Resource utililisation and situational awareness in a computer simulated decision task: A Pilot Study

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14. ABSTRACT

Achieving control of dynamic and complex situations is always challenging involving as it does the management of cognitive resources. It has been proposed that one of the leading causes of error in such dynamic environments is a generalised tendency to attempt to use more task resources than one?s cognitive capacity can sustain, termed the overutilisation of resources bias (Omodei, Wearing, McLennan & Hansen, 2001). The aim of the present study was to explicitly take into account individual differences in cognitive capacity in an investigation of this human tendency to overuse resources, and its proposed effect on decision making efficiency. Sixteen participants (i.e., 10 female and 6 male) aged between 18 and 32 years completed ten trials of the computer simulated forest fire-fighting task Networked Fire Chief (Omodei, Taranto & Wearing, 1999). Adopting a repeated measures design, all participants were administered two conditions: one in which they were given the maximum number of fire fighting resources they were observed to have been able to cognitively manage during earlier training trials (i.e., MANAGEABLE condition); and one in which they were given double the number of resources supplied in the MANAGEABLE condition (i.e., EXCESS condition). It was predicted that a tendency to overuse resources in the EXCESS condition would lead to cognitive overload with a higher experienced mental workload, poorer overall awareness of the situation, and subsequently poorer decision making performance compared to the MANAGEABLE condition. However, there was no significant difference found between conditions for any of these three variables. Further analyses revealed individual differences in the ability to appropriately adapt to the overabundance of resources in the EXCESS condition. It was concluded that individual flexibility in the quality of strategic thought allocated to resource usage, or in other words, the degree metacognitive control, may well be a major predictor of decision making efficiency in dynamic environments.

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Table of Contents

Table of contents……………………………………………………………………….*ii*

List of tables……………………………………………………………………....*v*

List of figures…………………………………………………………………….*vii*

List of appendices……………………………………………………………….*viii*

Abstract………………………………………………………………………….…..*1*

Introduction... *2*

Dynamic decision making in emergency situations 2
Studying dynamic decision making 3
Human cognitive processing limitations 3
The importance of situation awareness in dynamic decision making 4
Mental workload and dynamic decision making efficiency 5
An overutilisation of resources bias in dynamic decision making 6
Limitations of previous studies investigating the possible impact of an overutilisation of resources bias on dynamic decision making efficiency 8
The present study 9
Hypotheses 10

Method *10*

***Participants*... 10**

***Materials* 11**
Dynamic decision making task 11
Dynamic decision making scenarios 12

***Design* 14**

***Measures*.. 15**
Demographics 15
Dynamic decision making performance 15
Situation awareness 15
Subjective mental workload 16
Strategic thought allocated to appliance usage 17
Other subjective experiences in experimental conditions 18
Participant awareness of compulsion to use all appliances 18
Reliability of measures 19

***Procedure*... 19**

Results ***21***

Overview **21**

Preliminary Analyses **21**

Exclusion criteria 21
Demographics 22
Check for skewness and kurtosis 24
Check of adequacy of NFC task to study dynamic decision making 25

Main Research Analyses **28**

Main Hypotheses 28
Comparison of decision making performance scores between MANAGEABLE and EXCESS conditions 28
Comparison of mental workload between MANAGEABLE and EXCESS conditions 28
Comparison of SA between MANAGEABLE and EXCESS conditions 28

Supplementary Analyses **29**

Correlations between decision making performance and situation awareness 29
Correlations between situation awareness and mental workload 29
Correlations between decision making performance and mental workload 30
Self-perceived performance across appliance availability conditions 31
Self-perceived situation awareness across appliance availability conditions 33
Sub-components of mental effort across appliance availability conditions 34
Attention to all parts of the scenario 35
Participant awareness of compulsion to use all appliances 36
Maximum number of appliances that could be cognitively managed 36
Participants who performed exceptionally better in a particular condition 38

Discussion ***39***

Overview **39**

Preliminary Analyses **39**

Demographic variables 39
Adequacy of NFC Task for studying dynamic decision making 40

Main Research Analyses **40**

Comparisons of decision making performance and strategic thought between MANAGEABLE and EXCESS conditions 41
Comparison of mental workload between MANAGEABLE and EXCESS condtions 42
Comparison of SA between MANAGEABLE and EXCESS condtions 44

Potential Limitations of the present study **45**

Practical implications of findings **46**

Suggestions for future research **47**

Conclusion 49
References 50
Appendices 53

List of Tables

Table 1
Counterbalancing of appliance availability condition and landscape orientation 18

Table 2
Means and standard deviations of all demographic variables 29

Table 3
Correlations between all demographic variables and decision making performance scores.. 30

Table 4
Means and standard deviations of decision making performance and SAGAT scores.. 31

Table 5
Means, standard deviations and one-sample t-test results of core questions relating to participant mental workload and mental effort in MANAGEABLE and EXCESS conditions 33

Table 6
Means, standard deviations and one-sample t-test results of "heavier mental workload" and "more mental effort expended overall" items on the After All Trials Questionnaire 34

Table 7
Means and standard deviations of decision making performance and SAGAT scores in MANAGEABLE and EXCESS conditions, and the correlations between these scores.. 36

Table 8
Correlations among SAGAT scores and Mental Workload measures in MANAGEABLE and EXCESS conditions, and averaged across conditions 37

Table 9
Correlations among decision making performance scores and mental workload measures in each condition and averaged across conditions 38

Table 10
Correlations among self-perceived performance, mental workload and SAGAT scores.. 40

Table 11
Correlations between self-reported SA, SAGAT scores and decision making performance scores 41

Table 12
Means, standard deviations and one-sample t-test results of comparisons of mental effort sub-components between MANAGEABLE and EXCESS conditions.......... 42

Table 13
Correlations between the overall mental effort item and specific mental effort sub-components in the MANAGEABLE and EXCESS conditions 43

Table 14
Correlations between the maximum number of appliances manageable variable and performance scores, global SAGAT scores and all demographic variables 45

List of Figures

Figure 1
An experimental NFC scenario used in the present study 13

List of Appendices

Appendix A Background Information Questionnaire

Appendix B Situation Awareness Global Assessment Technique (SAGAT) Questionnaire

Appendix C Individual Trial Subjective Experience Questionnaire

Appendix D After All Trials Questionnaire

Appendix E Fire Chief Protocol

Appendix F Participant Decision Making Performance Scores and Maximum Number of Appliances Manageable

Abstract

Achieving control of dynamic and complex situations is always challenging involving as it does the management of cognitive resources. It has been proposed that one of the leading causes of error in such dynamic environments is a generalised tendency to attempt to use more task resources than one's cognitive capacity can sustain, termed the overutilisation of resources bias (Omodei, Wearing, McLennan & Hansen, 2001). The aim of the present study was to explicitly take into account individual differences in cognitive capacity in an investigation of this human tendency to overuse resources, and its proposed effect on decision making efficiency. Sixteen participants (i.e., 10 female and 6 male) aged between 18 and 32 years completed ten trials of the computer simulated forest fire-fighting task Networked Fire Chief (Omodei, Taranto & Wearing, 1999). Adopting a repeated measures design, all participants were administered two conditions: one in which they were given the maximum number of fire fighting resources they were observed to have been able to cognitively manage during earlier training trials (i.e., MANAGEABLE condition); and one in which they were given double the number of resources supplied in the MANAGEABLE condition (i.e., EXCESS condition). It was predicted that a tendency to overuse resources in the EXCESS condition would lead to cognitive overload with a higher experienced mental workload, poorer overall awareness of the situation, and subsequently poorer decision making performance compared to the MANAGEABLE condition. However, there was no significant difference found between conditions for any of these three variables. Further analyses revealed individual differences in the ability to appropriately adapt to the overabundance of resources in the EXCESS condition. It was concluded that individual flexibility in the quality of strategic thought allocated to resource usage, or in other words, the degree metacognitive control, may well be a major predictor of decision making efficiency in dynamic environments.

Introduction

Dynamic Decision Making in Emergency Situations

Humans generally spend a great proportion of their daily lives engaged in decision making activity. Often, the decision process is relatively simple, requiring a single choice from a number of alternatives in order to achieve a desired outcome (Brehmer, 1995). However, in real-world emergency management domains such as fire fighting and piloting aircraft, the decision process is quite complicated (Omodei, McLennan, Wearing & Speit, 2003). Furthermore, the consequences of decisions which are made are more serious. Specifically, the decision makers in such emergency management domains must attempt to control environments that are typically complex, dynamic and opaque, in order to protect life and property (Omodei et al., 2003). The environments are complex, as they demand a sequence of decisions and actions to be implemented in the face of a large array of information, ill-defined problems, competing goals, uncertainty, risk, and time pressure (Brehmer, 1995; Omodei, Wearing, McLennan & Hansen, 2001). The environments are dynamic in that they are subject to constant change: both independently of any decision input, and as a result of the decision makers’ actions (Omodei, Wearing, McLennan & Hansen, 2001). Finally, the environments are opaque in that the state and characteristics of the situation are not immediately obvious to the decision maker, requiring hypothesis formation and testing to reveal their nature (Brehmer, 1995).

Achieving control of such dynamic decision-making (DDM) environments is a formidable task, often requiring deep cognitive processing. In fact, errors in decision making are inevitable when the demands of a DDM task are simply beyond the decision makers’ cognitive capability (Omodei et al., 2003). Therefore, it is important to investigate the nature of decision errors under such limitations, and the extent to which such errors can be kept to a minimum. Such a research program can be expected to produce findings that will not only contribute to a better understanding of human cognitive functioning, but also allow for the identification of strategies for assisting people to optimise decision making performance in complex dynamic situations.

Studying Dynamic Decision Making

Until recently, the study of decision making in dynamic environments has been problematic. Field investigations have been criticised because they do not allow for the controlled and precise manipulation of relevant variables, and thus suffer poor internal validity (Omodei & Wearing, 2005). In contrast, laboratory experiments have been criticised for their poor external validity, whereby it has been argued they have not captured the true nature and complexity of real DDM environments (Brehmer, 1993).

Fortunately, recent advances in computer technology have allowed for the creation of computer simulated microworlds, in which scenarios can be developed that possess the key characteristics of a typical DDM environment, including dynamism, complexity, opaqueness and uncertainty, and thereby evoke similar psychological responses to those elicited in naturally occurring environments (Omodei, Wearing, McLennan & Hansen, 2001). In bridging the gap between the inherent complexity of field investigations and the rigor of laboratory studies, the use of computer simulated microworlds has become the dominant and certainly most effective method for studying decision making in dynamic environments (Omodei & Wearing, 2005).

One such computer-generated microworld program is known as Networked Fire Chief (NFC), which was developed by Omodei et al. (1999). Specifically, NFC allows the creation of simulated fire-fighting situations resembling those situations typically encountered by fire-fighters in reality. Results obtained from studies using computer simulated microworlds such as NFC have yielded valuable insight into the nature of human information processing

Cognitive Processing Limitations

When attempting to control DDM environments, decision-makers must attend to multiple sources of information, determine the meaning and value of this information, and select an appropriate response (Wickens, 2001). Unfortunately, humans have limited attention capacity, which means they are limited in the amount of information they can focus on and on the rate at which they can process such information. In fact, decision makers in dynamic environments tend to attend to items of information that are perceived as less important, sometimes at the cost of actually missing valuable information (Endsley, 2000b; Endsley & Rogers, 1998).

Subsequently, an important source of error in decision making is the failure to perceive valuable information. By way of example, Kuipers, Kappers, Van Holten, Van Bergen and Oosterveld (1990) investigated fatal errors in the controlled descent of fighter aircrafts in enemy terrain, and found that channelised attention and preoccupation with a potential malfunction were the most common causes of error.

Regardless of which information is selectively attended to, the active processing of such information occurs in working memory, with the outcome of such processing leading to information being either consolidated into long term memory or lost (Endsley, 2000). Generally, it has been argued that information remains resident in working memory for approximately 20 seconds before decay begins to occur unless it is actively rehearsed or used (Ploner, Gaymard, Rivaud, Agid & Pierrot-Deseilligny, 1998). Unfortunately, humans are limited in the number of resources they have available for meeting the computational and storage demands of information processing (Just & Carpenter, 1992). In fact, individuals differ in regard to their processing efficiency and speed. Hence, errors can also occur when relevant information is misinterpreted, forgotten or lost due to inadequate processing.

On a more specific level, decision errors are said to be more common when one has inadequate or incomplete knowledge regarding the current state of a dynamic environment, termed their situation awareness (SA) (Endsley, 1996). Hence, decrements in SA occur as a result of one’s working memory and therefore attention capacity limitations.

The Importance of Situation Awareness in Dynamic Decision Making

According to Omodei, Wearing, McLennan and Hansen’s (2001) Adaptive Control Model of Decision Making in DDM environments, humans generally allocate the greater part of their cognitive activity to situation assessment as distinct from action planning (an aspect of metacognition). Situation assessment involves perceiving and understanding the situation and therefore leads to the development and maintenance of situation awareness (SA). Endsley (1995a) proposed that SA has three distinct levels: the perception of elements in the environment (i.e., level 1 SA); the comprehension of their meaning (i.e., level 2 SA); and the projection of their future status (i.e., level 3 SA). The three levels of SA are hierarchical in the sense that one’s SA will be better the further one progresses through the three levels, starting at level 1 SA (Endsley, 1995a).

Because of its obvious importance in aviation, much of the early work on SA was conducted in this domain (Endsley, 1999a). Of particular relevance, Jones and Endsley (1995) conducted an extensive study of SA errors based on voluntary reports in NASA's Aviation Safety Reporting System (ASRS) database. Specific errors in SA included difficulty in perceiving a vital piece of information, failure to even acknowledge a vital piece of information, attention narrowing, external distractions, misperception and memory loss (Endsley, 1995a).

Partly because individuals differ in terms of their attention and strategies for dealing with inherent limitations in working memory capacity, individuals differ in their ability to acquire and maintain adequate SA. In support of this, Endsley and Bolstad (1994) investigated pilot SA in an air-to-air fighter sweep mission and found evidence of differences between individuals in their ability to achieve an adequate level of SA given the same situation. Specifically, the importance of spatial and perceptual skills, and to a lesser extent attention sharing and pattern matching were emphasised as predicting ability to acquire SA (Endsley & Bolstad, 1994).

It is important to note that even a person with perfect SA may still make the wrong decision, due to such factors as lack of knowledge or the adoption of poor decision strategies (Endsley, 1995a). Good SA can therefore be considered a factor that will increase the probability of good performance, but cannot necessarily guarantee it (Endsley, 1995a). There is no set threshold of SA that can guarantee a given level of performance (Endsley, 2000). Nonetheless, poor SA and resultant decision errors have been found to be more likely when mental workload is high.

Mental Workload and Decision Making Efficiency

Almost always in DDM environments, the decision maker will experience a high level of mental workload, given the quantity and complexity of demands placed on them. When there is more information available than one can process at a given time, this is referred to as cognitive overload (Joslyn & Hunt, 1998). Interestingly, Gibson, Orasanu, Villeda and Nygren (1997) reviewed the ASRS that contains information of aviation major incidents, and found that cognitive overload was amongst the major predictors of loss of SA and subsequent decision error.

In support of this, Endsley and Rodgers (1998) investigated errors in air traffic control and found that cognitive overload was primarily the cause of decision errors including misperceptions, and failures in monitoring and anticipation of the future

states. Other deleterious effects of such cognitive overload might include decrements in maintenance of adequate SA and impairment of high-level strategic thought (Omodei, Wearing, McLennan & Hansen, 2001). Therefore, mental workload has also been implicated as a major predictor of decision error in DDM environments. It is important to note that task load, defined as the demand imposed by a task, is generally distinguished from mental workload, defined as the controller's subjective experience of that demand (Hilburn & Jorna, 2001). A high task load will only impose a heavy mental workload on the decision maker when the demands of the task exceed the capacity of the decision maker's attention and working memory resources (Endsley, 1995a; Just & Carpenter, 1992). Furthermore, it is important to note that there are individual differences in the extent to which a high task load will impose a heavy mental workload (Brozovic, 2004; Wickens, 2002). This is because there are individual differences in overall cognitive capacity and subsequent processing efficiency (Just & Carpenter, 1992).

In investigating the phenomena of cognitive overload, Omodei et al. (2003) provided participants with twelve versus twenty-eight fire fighting appliances to command in the NFC fire fighting microworld, having assumed from pilot testing that twelve was the number of appliances that could be cognitively managed. It was found that the participants became significantly cognitively overloaded with twenty-eight appliances, to the extent that their decision making performance was significantly worse compared with when they had twelve appliances (Omodei et al., 2003). In a replication by Omodei and Wearing (2004), similar results were found, and it was concluded that any advantages offered by the availability of extra resources were offset by the tendency to use these resources regardless of their utility. Interestingly, it has been argued that whenever and whatever resource is made available, people feel compelled to use it, even when their cognitive system becomes so overloaded as to result in a degradation of decision making performance (Omodei, Wearing, McLennan & Hansen, 2001). This phenomenon has been termed the overutilisation bias.

An Overutilisation of Resources Bias in Dynamic Decision Making

It has been argued that a global belief shared by all humans is that "more is better" in regard to information and other decision resources which explains the tendency to overuse such resources (Omodei, Wearing, McLennan, Elliot & Clancy,

2001) relative to their allocation of other activities. In regard to the studies by Omodei et al. (2003) and Omodei and Wearing (2004), it was found that participants were not aware they were overusing fire fighting appliances in the NFC task, and participants could not detect that they were actually performing better in situations with fewer resources. Furthermore, the overutilisation bias was present in participants even after they were informed of the nature of this bias and told that using fewer resources would be more beneficial (Omodei & Wearing, 2004). Therefore, it has been argued that the overutilisation bias may well operate at a relatively unconscious level and that it is perhaps a deeply embedded cognitive structure (Omodei et al., 2003). In summary, these results point to the importance of a failure of metacognition.

A similar study by Brozovic (2004) involved giving participants eight (i.e., FEW condition) versus sixteen fire fighting appliances (MANY condition) to command in NFC, whereby eight was assumed to be the number of appliances that each participant could cognitively manage in the particular scenario created for this study. It was found that overuse of appliances did occur in the MANY condition, and the quality of strategic thought and level 2 and 3 SA were lower in the MANY condition, with high mental workload degrading decision making performance (Brozovic, 2004). It was concluded that in the presence of extra resources, there may be a trade-off between the quantity of resources used and the quality of cognitive processing associated with such resource use (i.e., quantity-quality trade-off) (Omodei, Wearing, McLennan & Hansen, 2001).

As briefly mentioned, the overutilisation bias appears to be non-specific, applying to all types of resources, whether this be for information gathering, opportunities for action or communication input (Omodei, Wearing, McLennan & Hansen, 2001). Using more resources obviously means more cognitive effort must be expended, which more often than not leads to cognitive overload (Wickens, 2001). Therefore, cognitive overload is said to be, to an extent, self-imposed (Brozovic, 2004; Omodei et al., 2003).

The most common argument regarding the cause of overutilisation is that it represents a general problem in metacognitive control, that is, one's ability to self-monitor and self-regulate the state of their working memory (Omodei, Wearing, McLennan, Elliot & Clancy, 2001; Omodei et al., 2003). Such self-evaluative control processes are usually aimed at maximising the continuing efficacy of a person's decisions by preventing limited working memory capacity being exceeded and

ensuring a balance between situation assessment, intention generation, and action selection (Omodei, Wearing, McLennan, Elliot & Clancy, 2001). However, often the attempt to maintain such a balance leads to more activities being undertaken than can be processed and a suboptimal allocation of mental resources among various aspects of the tasks (Brozovic, 2004; Omodei et al., 2003). More specifically, it has been argued that decision makers exhibit poor metacognitive control because they overestimate their own cognitive capacity, they feel a greater sense of control and ability when engaged in constant activity, and they prefer errors of commission over errors of omission (Omodei et al., 2003).

In summary, there are well-documented individual differences in skill, experience, goals, expectations, attention capacity, overall cognitive capacity and processing efficiency (Brozovic, 2004; Hilburn & Jorna, 2001; Just & Carpenter, 1992; Parasuraman & Hancock, 2001). Hence, there are individual differences in the ability to achieve control in DDM environments, and in the potential for error.

Limitations of Previous Studies Investigating the Possible Impact of an Overutilisation of Resources Bias on Dynamic Decision Making Efficiency

In all previous studies utilizing NFC to study the overutilisation bias with respect to the number of appliances available, the decision making performance, mental workload and SA of participants has been investigated by comparing results in two conditions: one where participants were given a fixed number of appliances assumed to be cognitively manageable; and one where they were given a fixed number of assumed over-abundance of appliances (Brozovic, 2004; Omodei & Wearing, 2004; Omodei, Wearing, McLennan & Hansen, 2001). That is, all participants have been given the same number of appliances in both appliance availability conditions. Assuming that all participants can cognitively manage the same number of appliances is problematic, considering the well-established individual differences in cognitive capacity as discussed above. In support of this, Brozovic (2004) concluded that there appears to be individual differences in the maximum number of appliances cognitively manageable. Therefore, for adequate investigation of the presumed overutilisation bias, researchers must control for such individual differences in the maximum number of appliances manageable.

Another limitation of past research using NFC to investigate the possible effects of the overutilisation bias on SA has been in the operationalisation of SA.

Generally, a version of Endsley's (1995b) Situation Awareness Global Assessment Technique (SAGAT) has been used as an objective measure of global SA. This involves pausing a simulation at a time unknwn to participants and then asking them to complete a series of questions regarding their awareness of the location of fires, the approximate distributions of appliances, fire warnings and wind conditions (Endsley, 1995b). The core problem with the SAGAT questionnaire is the time required for its administration.

Working memory is where dynamic information from the environment that informs present decision making would be resident, so an SA measure should tap into the contents of working memory (Endsley, 1999b). A significant issue for measures that attempt to tap into memory of an essentially non-verbal, spatio-temporal awareness is to what degree people can provide a verbal report on mental processes to make this information available for analysis (Endsley, 1999b). SAGAT questionnaires have generally comprised as many as eight questions, and sometimes have taken between 3-4 minutes to complete. Considering memory decay begins to occur after approximately 20 seconds, such a global SA measure may not be reliable. Interestingly, all previous studies using the SAGAT to measure SA in NFC have failed to find support for the hypothesised positive link between SA and decision making efficiency, nor for the hypothesised overlap between the various components of SA. This may be because the SAGAT measure typically used has been unreliable.

Endsley (1995a) has suggested that pilots' ability to report their SA via SAGAT was unaffected by the number of questions, and that memory decay would not be an issue provided the administration of the SAGAT *commenced* within 20 seconds after a simulation pause. However, as it has been briefly argued above, information can be expected to decay from working memory after 20 seconds (Ploner et al., 1998). Accordingly, the entire SAGAT would need to be *completed* within 20 seconds to obtain a reliable and valid measure of one's global SA.

The Present Study

The main aim of the present study was to re-investigate the possibility of an overutilisation of decision resources bias in NFC generated scenarios by (i) controlling for individual differences in the maximum number of appliances manageable, and (ii) using a version of the SAGAT that was able to be *completed* within 20 seconds of the simulation pause. Following this, the possible existence of an

overutilisation of resources bias and its true effect on decision making performance, mental workload and situation awareness could be investigated.

Hypotheses

In the present study, three hypotheses were proposed:

1) Decision making performance will be better in the MANAGEABLE (relatively few appliances) condition compared to the EXCESS (relatively many appliances) condition.
2) Mental Workload will be lower in the MANAGEABLE condition compared to the EXCESS condition.
3) SA will be better in the MANAGEABLE condition compared to the EXCESS condition.

Participants

Sixteen volunteer participants (6 male and 10 female) were recruited for this study, the majority of whom were undergraduate students at La Trobe University. The age range of participants was 18-32 years (M = 22.00, SD = 4.46). Participants were required for no more than five hours each and were compensated $13 per hour for their time. Participants were naïve to the purpose of the experiment.

Materials

Dynamic Decision Making Task

The NFC program was used in this study to create various simulated dynamic fire-fighting situations. Figure 1 illustrates one particular scenario used in this study to create a DDM environment.

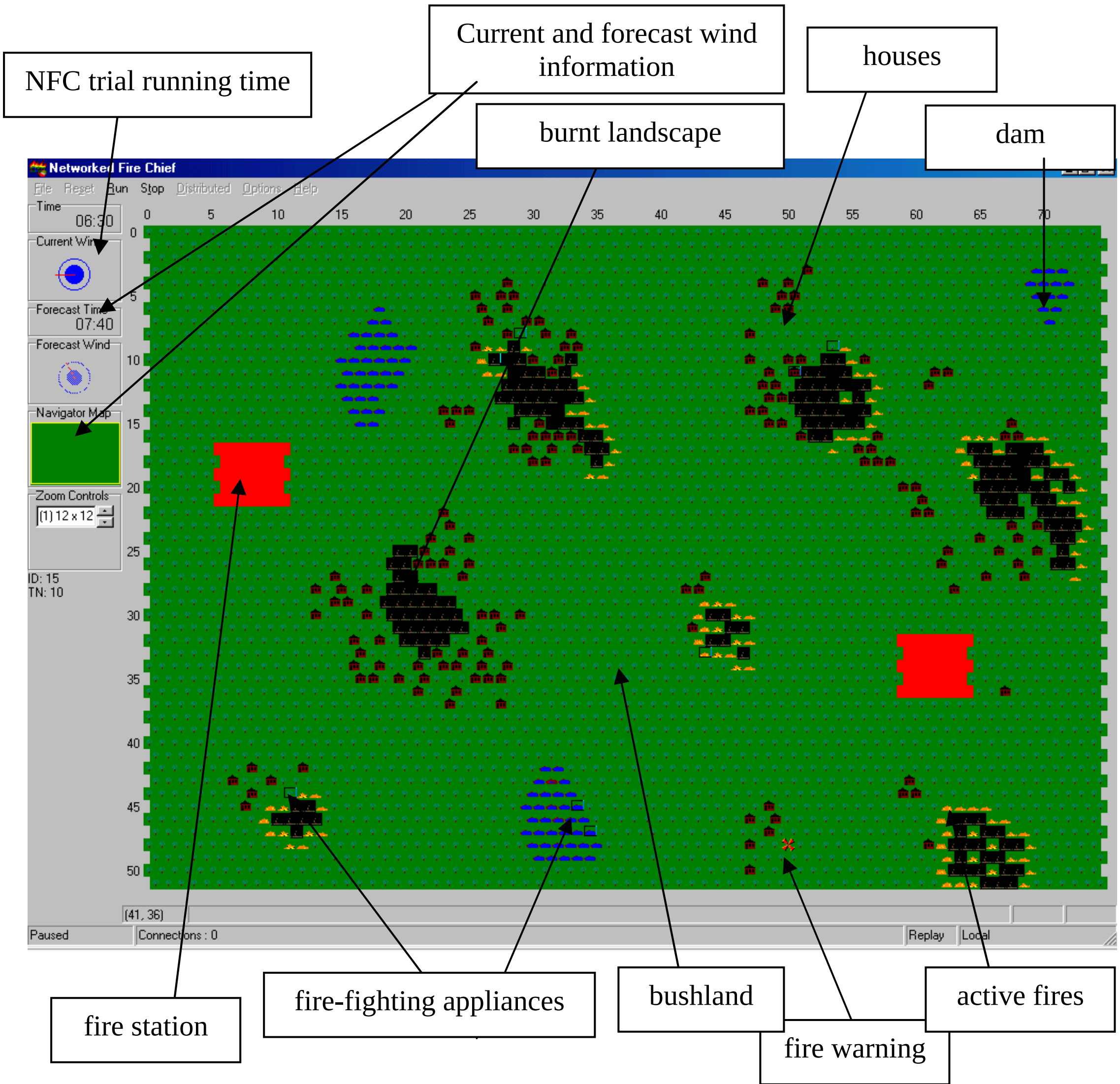

Figure 1. An experimental NFC scenario used in the present study.

The NFC program involves presenting participants with a landscape map on the computer screen and instructing them to control the spread of simulated fires using available fire fighting appliances. Participants move appliances by dragging them with the mouse and command the appliances to take action by clicking on them. The landscape map includes different landscape features assigned different asset

protection values, and participants are instructed to save as much valuable landscape as possible. Hence, participants must consider the value of landscape features in adopting a strategy for fighting the fires, whilst also considering current and forecast wind conditions, fire warnings and different fire spread rates. In addition, they must monitor the water level of each appliance and command the appliances to refill whenever necessary.

At the end of a NFC trial, the program provides an overall performance score statistic that indicates the overall value of landscape assets (as a percentage) remaining unburnt (Omodei, Wearing, McLennan & Hansen, 2001). In addition, NFC provides a mean idle time statistic at the end of a trial, which indicates the average amount of time the group of fire fighting appliances were left out of action. Furthermore, NFC provides a trial replay of each task. The ability of current computer simulation programs such as NFC to create complex and realistic DDM environments is well documented and hence, the use of NFC to study DDM in this study was warranted (Omodei & Wearing, 2004).

Dynamic Decision Making Scenarios

In this study, a total of eleven NFC trials were developed, comprising a demonstration trial, six practice trials of increasing difficulty and four experimental trials. All trials lasted 10 minutes each. The demonstration and practice trials provided a chance for the participants to gain the appropriate knowledge and skill needed for the NFC program. Furthermore, these trials were used by the experimenter to progressively assess the maximum number of fire fighting appliances that each participant could cognitively manage. Finally, the experimental trials were designed to assess the participant’s decision-making skill, mental workload and SA under the two appliance availability conditions (details provided below).

The scenarios were designed so that saving a house was worth 100 points, while saving bushland was only worth 1 point. Participants were told of these values and therefore instructed to strictly prioritize saving houses when completing a trial. Participants were also informed of the fact that fires spread faster through bushland than houses, and that the fires spread in accordance with the current wind direction and strength.

In all NFC scenarios used in previous studies, there were houses on the landscape that were not at risk of being burned. Hence, these houses remained intact

even if a participant did not initiate any commands in the entire ten minutes of the trial. This would reduce the *sensitivity* and therefore reliability of the final overall performance score as a measure of decision making skill. In the present study therefore, the NFC trials were designed so that all the houses were at risk of being burnt. Hence, the trials were more sensitive to differences in decision making skill. Specifically, participants who prioritised well and made appropriate decisions would save more houses than a less skilled participant, and would subsequently achieve a significantly higher performance score.

The experimental trials were designed so that they would be cognitively challenging for the more skilled participants, yet not overwhelmingly difficult for the less skilled participants. Participants were required to expend substantial mental effort attending to multiple critical fires, random fire warnings and frequent wind changes, whilst regularly monitoring and commanding the various fire fighting appliances.

There were two experimental conditions, termed the MANAGEABLE and EXCESS conditions. In the MANAGEABLE condition, participants were given the maximum number of fire fighting appliances that they were assessed as being able to cognitively manage. This number was chosen based upon observation of the participants mean idle times in the practice trials (see procedure). In the EXCESS condition, participants were given double the number of fire fighting appliances they would have access to in the MANAGEABLE condition. This number of appliances was judged to be substantially more than the number that participants should be able to cognitively manage.

The fire-fighting appliances were programmed to arrive at a requested destination immediately following the initiation of the command. While fire fighting appliances in real life are obviously not as quick responding, having the fire fighting appliances travel at a slower rate would have affected the overall mean idle time, which was being used as an indication of the maximum number of fire trucks one could cognitively manage. Therefore, full realism in this aspect of fire fighting appliance behaviour was sacrificed for more precise and controlled manipulation of the number of appliances one could cognitively manage. Pilot testing indicated this compromise was readily accepted and adapted to by research participants.

For the experimental trials, one scenario was created and then horizontal, vertical, and vertical-horizontal reflections of the original scenario were used to create four scenarios that were equivalent in landscape features, fire and wind behaviour,

and difficulty, but not recognised as such by the participants. Two sets of experimental trials were needed, as the administration of the SAGAT immediately post trial was considered likely to interfere with the administration of self-report questionnaires (and vice versa). The first two experimental trials were used to administer the objective SA assessment. The second two experimental trials were used to administer the Individual Trial Subjective Experience Questionnaire (see Appendix C) and the After All Trials Questionnaire (see Appendix D), and to collect performance score data. The four experimental trials were counterbalanced in terms of appliance availability condition and landscape orientation. The method of counterbalancing can be seen in Table 1.

Table 1

Counterbalancing of appliance availability condition and landscape orientation

Experimental Trial	Condition and scenario	Participants 1,5,9,13	Participants 2,6,10,14	Participants 3,7,11,15	Participants 4,8,12,16
1	Condition Scenario	Manageable Normal	Manageable Vertical	Excess Horizontal	Excess Vertical-horizontal
2	Condition Scenario	Excess Vertical	Excess Normal	Manageable Vertical-horizontal	Manageable Horizontal
3	Condition Scenario	Manageable Vertical-horizontal	Excess Vertical-horizontal	Excess Vertical	Manageable Vertical
4	Condition Scenario	Excess Horizontal	Manageable Horizontal	Manageable Normal	Excess Normal

Design

The present study used a within-subjects, repeated measures design to examine decision-making performance, SA and mental workload in both the MANAGEABLE and EXCESS conditions. Decision-making performance was the primary dependant variable, which was operationalised as the performance score in terms of value of landscape assets saved in each NFC trial. Other dependent variables were SA, which was measured objectively by the SAGAT and subjectively via self-report, and mental workload, which was also measured via self-report.

Measures

Demographics

A background information questionnaire was used to gather general background information about participants, including their age, gender, computer usage, skills and confidence, and decision-making experience in DDM situations (see appendix A).

DDM Performance

A performance score was automatically recorded by NFC after each trial, which indicated the value of landscape assets (as a percentage) remaining unburnt at the end of a trial (Omodei, Wearing, McLennan and Hansen, 2001). Such performance scores served as the primary measure of the participants DDM skill.

For analyses of the extent to which each individuals' score on the EXCESS condition trial differed from their score on the corresponding MANAGEABLE condition trial, residualised change scores instead of raw change scores were calculated and used. Residualised change scores have the advantage over raw change scores in that they remove any change due to regression to the mean in correlated variables (Tabachnick & Fidell, 2001).

Situation Awareness

As an objective assessment of SA, a shortened version of Endsley's (1995b) Situation Awareness Global Assessment Technique (SAGAT) was used. In the first two experimental trials comprising MANAGEABLE and EXCESS conditions, the simulation was paused at an unknown time to participants and only the bare landscape (i.e., minus fire and fire effects) was re-presented on the computer screen. On a transparent acetate sheet attached to the screen, participants were then asked to draw the location of the perimeter of the fire that was threatening the most valuable landscape.

This item regarding awareness of the most threatening fire was judged to be a measure of global SA. Specifically, participants had to perceive the wind strength and direction in addition to the location of fires (level 1 SA), before comprehending this information (level 2 SA) to decide which fire would be threatening the most valuable landscape (i.e., houses) in the near future (level 3 SA). In the SAGAT questionnaire, the participants also had to mark the location where the next fire was due to break out,

which required memory of the location of a fire warning that had been presented immediately prior to the pause in the simulation. In addition, participants had to mark the strength and direction of the wind immediately prior to the pause (see appendix B). Unfortunately however, the first fire perimeter item took the full 20 seconds to complete for most participants, so the data obtained from additional assessments were not used. Specifically, memory decay would have occurred prior to the completion of the additional assessments, so they would not have been reliable. Subsequently, the fire perimeter item was solely used as the global measure of SA for all analyses.

The drawings on the transparent acetate sheet were eventually compared to the real scenario, and an objective score of global SA was calculated according to the following scoring code: participants received a score out of 9 for awareness of the most threatening fire (i.e., 1 = circled an area that was not particularly close to any fire, 9 = precisely circled the entire most threatening fire).

The pausing of the simulation occurred at 3:40 mins for all participants, although the timing of the pause was unknown to the participants. This was an appropriate time that was sufficiently cognitively demanding, whereby there were numerous large and small fires that had broken out. Certainly, the number and severity of fires at this time varied among participants according to their previous commands and skill level. However, the coding system used for the marking of the SAGAT was explicitly designed to take these differences into account, thus ensuring the measure of SA was independent of decision making performance.

The participant's subjective rating of their SA was also measured, using several self-report items in the Individual Trial Subjective Experience Questionnaire completed after the final two experimental trials (see appendix C). Participants responded to questions such as: 'How would you describe your overall awareness of what was going on during the last Fire Chief trial?' on a 9-point Likert-type scale, 1 = very low awareness, 9 = very high awareness.

Subjective Mental Workload

The level of mental workload experienced by participants in each condition was measured via self-report in the Individual Trial Subjective Experience Questionnaire. Specifically, participants responded to the question "How much mental effort did you expend overall" on a 9-point Likert-type scale (1 = no mental effort, 9 = a great deal of mental effort), and this item was used as the main measure of mental

workload. Additionally, sub-components of mental effort expenditure were assessed in both conditions, whereby participants indicated on a 9-point Likert-type scale (1 = no mental effort, 9 = a great deal of mental effort) the amount of mental effort they expended on (i) scanning the environment for changes, (ii) deciding what action to take next, (iii) implementing the actions, (iv) controlling emotional reactions and (v) checking the right approach was being used (see Appendix C). As numerous participants verbalised confusion about the meaning of items assessing and comparing the amount of mental effort expended controlling emotions, these items were excluded from analyses. It should be noted that responses to these items assessing mental effort expended controlling emotions were not required for interpretation of the results testing the main research hypothesis.

Direct comparisons of the level of overall mental workload experienced and of the sub-components of mental effort expenditure between conditions were also obtained in the After All Trials Questionnaire completed at the end testing (see Appendix D). For example, participant one responded to questions on a 9-point Likert-type scale; 1 = more mental effort overall when I had MANAGEABLE appliances, 5 = the same, and 9 = more mental effort overall when I had EXCESS appliances (note the order of presentation of these anchors corresponded to the order in which the trial conditions were administered to each participant). It is important to note that the items assessing mental effort expended overall and the extent to which participants had a heavy mental workload were also used as a check that the NFC trials were sufficiently cognitively demanding (see Appendix C). Specifically, a score above 5 on the 9-point Likert-type scale, indicated that a greater than moderate level was necessary for the NFC trials to be considered cognitively demanding.

Strategic Thought Allocated to Appliance Usage

The items assessing the amount of mental effort that participants expended on checking the right approach was being used and deciding what action to take next were also specifically used as a measure of the strategic thought participants allocated to appliance usage. The item assessing mental effort scanning the environment for changes was also specifically used as a measure of mental effort allocated to situation assessment and SA maintaining procedures, so this item was not considered as a measure of strategic thought. Note that the item assessing mental effort expended implementing actions was not considered as a measure of strategic thought, because

this item was merely measuring the mental effort allocated to the *physical* action of appliances, not their strategic placement. For example, participants with slow psychomotor skill would expend a high amount of mental effort actually moving the appliances and clicking on them to take action and vice-versa.

Other Subjective Experiences in Experimental Conditions

Differences in participants' feelings of confidence and perceived performance between the MANAGEABLE and EXCESS conditions were assessed by self-report items using a 9-point Likert-type scale on the After All Trials Questionnaire (see Appendix D). Self-perceived performance in both MANAGEABLE and EXCESS conditions was also assessed, using a 9-point Likert-type scale on the Individual Trial Subjective Experience Questionnaire (see Appendix C). Also included in this questionnaire was an item asking participants "How determined were you to perform as well as you could on the last Fire Chief trial", whereby participants had to report above 5 on the 9-point Likert-type scale (1= not determined at all, 5 = moderately determined, 9 = very determined) to be included in the analyses (see Appendix C).

Participant Awareness of Compulsion to Use All Appliances

In all past studies using NFC to study the possibility of an overutilisation of resources bias, the item on the After All Trials Questionnaire "To what extent did you feel compelled to use all the fire trucks at your disposal?" has been used as a measure of participant's compulsion to use all available appliances. As has been mentioned, the overutilisation bias may well operate on a relatively unconscious level, so decision makers may not always be consciously aware of their compulsion to use all available resources (Omodei et al., 2003). Therefore, the self-report measure of compulsion may not be reliable. Certainly, there is strong evidence in the literature on NFC that people generally feel compelled to use all available resources provided to them. Therefore, this item may be better used as a measure of the extent to which participants are aware of such a compulsion. Hence, it was included in the present study for this reason.

Note that participant's awareness of the extent of compulsion to use all appliances was not assessed after each appliance availability condition separately, so as not to introduce demand characteristics by revealing the primary aim of the study before both trial conditions had been administered.

Reliability of Measures

The only potential measure of reliability of items used after each resource level condition would be to correlate responses on the same item across these two experimental conditions (effectively giving lower-bound estimates, as there may well be valid differences in these experiences across individuals and trials). Considering the small sample size used in the present study, such lower-bound estimates of reliability would themselves have been of low reliability. Realistically, there was no method for providing direct evidence for reliability of the measures adopted in the present study, except for SA (see below). Fortunately however, past studies investigating the overutilisation bias using NFC have reported high reliability of all such measures, and hence their use in the present study was warranted (Omodei, Wearing, McLennan & Hansen, 2001). Particularly worthy of mention, high reliability of performance scores as a measure of DDM skill have been found, with correlations of .7 or greater being consistently reported (Bozovic, 2004; Omodei, Wearing, McLennan & Hansen).

The inter-rater reliability of the accuracy of the recalled fire perimeter item as a measure of global SA was found to be satifactory. Specifically, participants' responses on the SAGAT questionnaire were marked by two researchers using the same SAGAT marking code. Pearson correlations between both researchers' ratings of SAGAT scores presented inter-rater reliability of r = .98, p< .01 for the MANAGEABLE condition and r = .81, p< .01 for the EXCESS condition.

Procedure

Each participant was individually tested. After reading an information statement, the participants completed the written informed consent form and the background questionnaire. Participants were then trained in the use of the NFC program through the presentation of a demonstration trial. To ensure all participants received the same instructions, a scripted fire chief protocol was read to each participant explaining the features of the program, the aim of the simulation and the details for operating the simulated fire fighting appliances (see appendix E).

The participants then completed the first practice trial, where they had access to 4 fire fighting appliances. Pilot testing revealed that even the least skilled participants could handle 4 appliances quite well, so this seemed an appropriate

number of appliances to make available for the first trial. Prior to completing the second practice trial, appropriate adjustments to the number of appliances available for each participant were made upon consideration of the mean idle time statistic of trial one. Specifically, pilot testing on five participants revealed that if participants appeared to be just managing all appliances available to them, this was associated with a mean idle time of approximately 70%. While seemingly high, this value takes into account the time participants spent pausing to strategise and to implement individual actions. Therefore, one fire fighting appliance additional to the number available in the previous trial was provided if the mean idle time of the previous trial was below 70%. Otherwise, 4 fire trucks were made available for the second practice trial. It was assumed that participants would get better in NFC with practice, which in fact was the case.

In the second practice trial, the trial was paused in order to provide practice in completing the SAGAT questionnaire. After the SAGAT was completed, the trial was resumed. Following this, the remaining three practice trials were completed, which were of progressively increasing difficulty. After each practice trial, participants had a break, during which time the experimenter noted the mean idle time and made appropriate changes to the number of appliances available in the next practice trial. In the case where the mean idle time of the previous trial was above 70%, one appliance was subtracted from the number available in the previous trial. By the end of the fifth practice trial, the number of appliances that gave a mean idle time closest to 70% was recorded to be the maximum number of appliances that the particular participant could cognitively manage (see appendix F). By this stage, it was expected that participants had reached stability in the maximum number of appliances they could manage.

After completion of the last practice trial, participants were given a 45 minute break. Upon return from their break, participants completed a refresher trial before completing the first two experimental trials. In both of these experimental trials, the simulation was paused at the predetermined time of 3:40 mins and the SAGAT questionnaire was administered before the trial resumed. After a 10 minute break, participants then completed the last two experimental trials, and the Individual Trial Subjective Experience Questionnaire was administered after each of these trials. Finally, the After All Trials Questionnaire was completed. Participants were thanked for their time, paid, and allowed to leave.

Results

Overview

The results of preliminary analyses are presented in the first section, which comprise (i) a check that all participants had sufficient determination levels and understanding of the NFC task, (ii) the relationships of the demographic variables to the main dependent variables, namely decision making performance, SA and mental workload, (iii) a check of skewness and kurtosis values for decision making performance scores, SAGAT scores and all subjective experience variables, and (iv) a check of the adequacy of the NFC task to study DDM. The results of analyses that address the main study hypotheses are presented in the second section. Finally, the results of supplementary analyses are presented, intended to assist with the interpretation of the main results.

Note that considering the small sample size used in this study, all correlation results, both in preliminary and supplementary analyses must be interpreted with caution. Nonetheless, the results of the overall pattern of such correlations are considered in the interpretation of the main results, for which there was adequate statistical power.

Preliminary Analyses

Exclusion Criteria

All participants reported determination levels above the 5 cut-off value. However, one participant who had limited English vocabulary and limited comprehension of the English language was excluded from all analyses, because of communication difficulties. It appeared he did not understand the requirements of the NFC tasks, further supported by observation of his consistently poor performance scores in all NFC trials. The mean determination score of remaining participants was 7.85 (SD = 0.99) (on a 9-point Likert-type scale).

Demographics

The means and standard deviations of all the demographic variables for the remaining 15 participants (5 male and 10 female) can be seen in TablTable 2

Means and standard deviations of all demographic variables

	M	*SD*
Demographic Variable		
Participant age	21.47	4.05
Days a week using computer	5.33	2.35
Rating of computer skills	6.33	2.16
How comfortable moving mouse	8.27	.80
How often play computer games	4.60	2.82
Rating of coping ability under pressure	6.33	.90
Experience with decision making under time pressure	5.13	1.55

Note: N = 15, Responses were given on a 9-point Likert-type scale, except for “days per week using computer” and “participant age”.

As can be seen in Table 2, it appears that participants overall were quite skilled and comfortable computer users and had a reasonable amount of experience with decision making in time pressured situations. Pearson correlations were calculated between each demographic variable and the main study dependent variables. Table 3 contains the results of such correlations with performance score in each appliance availability condition. There were no significant correlations of the demographic variables with SA or mental workload.

Table 3

Correlations between all demographic variables and decision making performance scores

	Performance Score		Difference in Performance
	MANAGEABLE	EXCESS	MANAGEABLE-EXCESS
Demographic Variable			
Participant age	-.07	.16	-.30
Days a week using computer	.27	.19	.14
Rating of computer skills	.10	.50	-.52
How comfortable moving mouse	.23	.32	-.10
How often play computer games	.75**	.71**	.12
Rating of coping ability under pressure	.01	.26	-.32
Experience with decision making under time pressure	.22	.24	-.00

Note: ***p*< .01 (2-tailed), N = 15.

As can be seen in Table 3, how often participants played computer games significantly correlated with their decision making performance in both the MANAGEABLE and the EXCESS conditions. There were no other substantial

correlations between the demographic variables and performance or variation in performance between the two conditions.

Independent samples *t*-tests were performed to test if gender had a significant affect on performance. Results indicated that males performed slightly better in the MANAGEABLE condition than females (Males: *M* = 80.19, *SD* = 13.67; Females: *M* = 67.30, *SD* = 14.17), yet this difference was not significant, t(13) = 1.68, $p>.05$ (two-tailed), *d* = .93. Interestingly, males performed significantly better in the EXCESS condition compared to females (Males: *M* = 84.48, *SD* = 8.20; Females: *M* = 69.68, *SD* = 13.87), t(13) = 2.18, $p<.05$ (two-tailed), *d* = 1.21. Note that the sample size for between-groups comparisons was very low.

Check for Skewness and Kurtosis

Skewness and kurtosis values for NFC performance scores, SAGAT scores and all subjective experience variables were less than 3 SE units and therefore assessed as normal (Tabachnick & Fidell, 2001). The raw performance scores achieved by individuals in the experimental trials can be seen in Appendix F. The means and standard deviations of performance and SAGAT scores can be seen in Table 4.

Table 4

Means and standard deviations of decision making performance and SAGAT scores

	M	SD	Min	Max	n
Performance Scores					
MANAGEABLE	71.60	14.90	51.13	96.41	15
EXCESS	74.61	13.97	46.71	98.95	15
SAGAT Scores					
MANAGEABLE	6.86	1.80	3.00	8.00	
EXCESS	6.36	1.87	3.00	9.00	14

Note: Performance scores were out of 100, SAGAT scores were given out of 9.

As can be seen in Table 4, the range of performance scores in experimental trials was quite large, which suggests that the method of making each house in a trial at risk of being burnt was effective for distinguishing poor from efficient decision makers. The range of SAGAT scores was also quite large, which suggests that participants did differ in regards to their SA.

The baseline percentage value was approximately 25.71% for decision making performance in both experimental trial conditions. This number represents the average overall value of landscape assets remaining unburnt as a percentage at the end of an experimental trial if no actions were taken at all (Omodei, Wearing, McLennan & Hansen, 2001). The counterbalancing of landscape orientation across appliance availability condition ensured that any remaining slight differences in baseline values between landscape orientations were controlled for experimentally.

Check of Adequacy of NFC Task to Study DDM

Table 5 shows the means and standard deviations of participants' responses to the mental workload and mental effort items on the Individual Trial Subjective Experience Questionnaire.

Table 5

Means, standard deviations and one-sample t-test results of core questions relating to participant mental workload and mental effort in MANAGEABLE and EXCESS conditions

	MANAGEABLE			EXCESS		
	M	*SD*	One-sample *t*-test (two-tailed)	M	*SD*	One-sample *t*-test (two-tailed)
Mental Workload Measure						
Heavy workload	6.83	1.36	$t(14) = 5.23$, $p = .00$	6.67	1.54	$t(14) = 4.18$, $p = .00$
Mental effort overall	6.60	1.45	$t(14) = 4.26$, $p = .00$	6.40	1.30	$t(14) = 4.18$, $p = .00$
Difficulty managing mental workload	4.77	1.82	$t(14) = -.50$, $p > .05$	4.53	2.03	$t(14) = -.89$, $p = > .05$

Note: N = 15, Responses were given on a 9-point Likert-type scale, where 5 represented a moderate level of mental workload. One-sample *t*-test was performed against a test value of 5, which indicated a moderate level.

As can be seen in Table 5, mean levels of reported workload and mental effort were significantly greater than a moderate level in both conditions. Therefore, NFC was deemed to be sufficiently demanding for studying DDM. However, mean levels of difficulty managing mental workload were not significantly greater than a moderate level in either condition.

Paired samples *t*-tests were also performed, which revealed no significant differences in workload, difficulty in managing mental workload and mental effort expended overall items between MANAGEABLE and EXCESS conditions, $t(14) = .37$, $p>.05$ (two-tailed), $d = .20$, $t(14) = .56$, $p>.05$ (two-tailed), $d = .30$, $t(14) = .46$, $p>.05$ (two-tailed), $d = .25$, respectively. Table 6 contains the means and standard deviations for two items on the Comparison of Trials Questionnaire, which required participants to rate in which appliance availability condition they had a heavier mental workload and expended more mental effort overall.

Table 6

Means, standard deviations and one-sample t-test results of "heavier mental workload" and "more mental effort expended overall" items on the After All Trials Questionnaire

	M	*SD*	One-sample *t*-test (two-tailed)
Heavier mental workload	5.13	2.62	$t(14) = .20$, $p>.05$
More mental effort overall	5.33	2.29	$t(14) = .56$, $p>.05$

Note: N = 15, Responses were given on a 9-point Likert-type scale: 1 = heavier mental workload/ more mental effort overall when I had MANAGEABLE fire trucks; 5 = the same, and 9 = heavier mental workload/ more mental effort overall when I had EXCESS fire trucks. One-sample *t*-test was performed against a test value of 5, which participants would have circled if they felt no difference between conditions.

As can be seen in Table 6, participants did not experience a heavier mental workload or expend more mental effort overall in any appliance availability condition, This means that mental effort expended could not account for any of the variance in performance scores across appliance availability conditions.

Main Research Analyses

Main Hypotheses

1) Comparison of decision making performance scores between MANAGEABLE and EXCESS conditions

It was expected that participants would perform better in the MANAGEABLE condition compared to the EXCESS condition. A paired samples *t*-test was performed on decision making performance, which revealed no statistically significant difference between the MANAGEABLE condition (*M* = 71.60, *SD* = 14.90) and the EXCESS condition (*M* = 74.61, *SD* = 13.97), t(14) = -1.08, p>.05 (two-tailed), *d* = .58.

2) Comparison of mental workload between MANAGEABLE and EXCESS conditions

It was expected that participants would experience a lower degree of mental workload in the MANAGEABLE condition compared to the EXCESS condition. A paired samples *t*-test was performed on the item regarding mental effort expended overall, which revealed no significant difference between the MANAGEABLE condition (*M* = 6.60, *SD* = 1.45) and the EXCESS condition (*M* = 6.40, *SD* = 1.30), t(14) = .46, *p*>.05 (two-tailed), *d* = .25.

3) Comparison of situation awareness between MANAGEABLE and EXCESS conditions

It was expected that participants would have better SA in the MANAGEABLE condition compared to the EXCESS condition. A paired samples *t*-test was performed on global SAGAT scores, which revealed no significant difference between the MANAGEABLE condition (*M* = 6.86, *SD* = 1.80) and the EXCESS condition (*M* = 6.36, *SD* = 1.87), t(13) = .63, *p*>.05 (two-tailed), *d* = .35.

Supplementary Analyses

Correlations Between Decision Making Performance and Situation Awareness

Pearson correlations between decision making performance and global SAGAT scores were conducted, the results of which can be seen in Table 7.

Table 7

Means and standard deviations of decision making performance and SAGAT scores in MANAGEABLE and EXCESS conditions, and the correlations between these scores

	M	*SD*	*n*	*r*
MANAGEABLE				
SAGAT score	6.86	1.79	14	.24
Performance score	71.60	14.90	15	
EXCESS				
SAGAT score	6.36	1.87	14	.34
Performance score	74.61	13.97	15	
AVERAGE across conditions				
SAGAT score	6.61	1.10	15	
Performance score	73.11	13.39	14	.46

Note: SAGAT score is out of 9, Performance score is out of 100.

As can be seen in Table 7, there were no significant correlations between performance scores and SAGAT scores. However, the correlations were approaching significance, especially for the EXCESS conditions and averaged across conditions.

Correlations Between Situation Awareness and Mental Workload

Pearson correlations between global SA and mental workload were conducted, the results to which can be seen in Table 8.

Table 8

Correlations among SAGAT scores and mental workload measures in MANAGEABLE and EXCESS conditions, and averaged across conditions

	SAGAT score		
	MANAGEABLE	EXCESS	Average
Mental Workload Measure			
Heavy workload	.16	-.47*	-.23
Mental effort overall	.06	-.57*	-.37
Difficulty managing mental workload	-.53*	.00	-.42

Note: The average of SAGAT scores across the two conditions was used for the correlation with the average of each mental workload measure across conditions, N = 15 for mental workload measures, N = 14 for SAGAT scores *p<.05 (1-tailed).

As can be seen in Table 8, the general pattern of correlations was in the expected negative direction. A significant relationship was found between the extent to which participants felt they had a heavy mental workload and their SAGAT score in the EXCESS condition, r = -.47. Additionally, a significant relationship was found between the participants' experienced mental effort overall and their SAGAT score in the EXCESS condition, r = -.57. Meanwhile, a significant relationship was found between participants' reports of their difficulty managing mental workload and their SAGAT score in the MANAGEABLE condition, r = -.53.

Correlations Between Decision Making Performance and Mental Workload

Pearson correlations between mental workload measures and decision making performance were conducted, the results of which can be seen in Table 9.

Table 9

Correlations among decision making performance scores and mental workload measures in each condition and averaged across conditions

	Performance score		
	MANAGEABLE	EXCESS	Average
Mental Workload Measure			
Heavy workload	.06	-.01	.15
Mental effort overall	.07	-.34	-.05
Difficulty managing mental workload	-.10	-.25	-.19

Note: The average of each mental workload item across the MANAGEABLE and EXCESS conditions was correlated with average performance, N = 15.

As can be seen in Table 9, none of the mental workload measures correlated with decision making performance in either condition or across conditions.

Self-perceived Performance Across Appliance Availability Conditions

Participants were asked to subjectively rate their performance on a 9-point Likert-type scale for both the MANAGEABLE and EXCESS conditions on the Individual Trial Subjective Experience Questionnaire. A paired samples *t*-test was performed, which revealed no significant difference in perceived performance between the MANAGEABLE condition (M = 6.67, SD = 1.11, n = *15*) and the EXCESS condition (M = 6.00, SD = 1.36, n = *15*), t(14)= 1.67, p>.05 (two-tailed), d = .89. Interestingly, the correlation between self-reported performance in MANAGEABLE and EXCESS conditions was low (r = .24) despite the much higher correlation between objective performance in both conditions (r = .72). As there may well be strong actual differences in self-perceived performance across conditions, this low correlation may perhaps best be interpreted as indicating such actual differences.

On the After All Trials Questionnaire, participants were asked to subjectively rate which condition they felt they had performed best on by responding on a 9-point

Likert-type scale (i.e., 1 = performed best when I had MANAGEABLE appliances, 5 = performed equally well in both conditions, 9 = performed best when I had EXCESS appliances). A one sample *t*-test performed against a test value of 5 revealed that participants generally did not feel they performed better in any particular condition ($M = 5.13$, $SD = 2.42$, $n = 15$), $t(14) = .21$, $p>.05$ (2-tailed).

The correlation between participant's self-perceptions of performance and actual performance scores in the MANAGEABLE condition was slightly insignificant, $r = .38$, $p>.05$. Participant's self-perceptions of performance did correlate significantly with performance scores in the EXCESS condition, $r = .59$, $p<.05$. Interpreted simply, the results suggest that participants seemed to have quite good awareness of their level of performance, specifically in the EXCESS condition, but were insensitive to differences in their performance across the two conditions.

Pearson correlations were performed between participants' self-perceptions of their performance, mental workload, and global SA, the results of which can be seen in Table 10.

Table 10

Correlations among self-perceived performance, mental workload, and SAGAT scores

	Self-perceived performance		
	MANAGEABLE	EXCESS	Average
Mental Workload Measure			
Heavy workload	-.11	-.31	-.11
Mental effort overall	-.18	-.48*	-.08
Difficulty managing mental workload	-.16	-.41	-.21
SAGAT score			
Awareness of threatening fire item	.31	.74**	.75**

Note: *p<.05 (1-tailed), **p<.01 (1-tailed), N = 15 for correlations with mental workload and self-reported SA, N = 14 for correlations with SAGAT.

As can be seen in Table 10, there were few statistically significant relationships between self-perceived performance and mental workload. However, a significant negative correlation was found between mental effort expended overall and self-perceived performance in the EXCESS condition. Specifically, as participants' mental effort overall increased, their self-perceived performance decreased in the EXCESS condition.

SAGAT scores were significantly correlated to self-perceived performance in the EXCESS condition and averaged across conditions, but not in the MANAGEABLE condition. In examining the overall pattern of these correlations, it can be noted that stronger associations were obtained in the EXCESS condition than in the MANAGEABLE condition.

Self-perceived Situation Awareness Across Appliance Availability Conditions

Pearson correlations were performed between participants self-perceived SA, decision making performance scores and SAGAT scores, the results of which can be seen in Table 11.

Table 11

Correlations between self-reported SA, SAGAT scores and decision making performance scores

	Global SAGAT Score			Performance Score		
	MANAGEABLE	EXCESS	Ave.	MANAGEABLE	EXCESS	Ave
Self reported Situation Awareness						
Overall Awareness	.42	-.07	.26	-.06	-.04	.07

Note: The average of Global SAGAT scores and Performance scores across MANAGEABLE and EXCESS conditions was correlated with average self-reported SA, N = 15 for correlations with self-reported SA and performance score, N = 14 for correlations with SAGAT scores.

As can be seen in Table 11, there were no statistically significant relationships between self-reported overall SA, SAGAT scores and performance scores. Consistent with Brozovic (2004), the lack of correlation between self-reported SA and SAGAT scores is not surprising, considering that participants had only their perceptions of

what was happening in the task, not what was realistically happening (Brozovic, 2004). Likewise therefore, the fact the participants' general poor knowledge of their SA was not related to their actual decision making performance is also not surprising. Additionally, self-perceived performance was not significantly related to self-perceived SA.

Sub-components of Mental Effort Across Appliance Availability Conditions

Means and standard deviations of comparisons of mental effort sub-components across the MANAGEABLE and EXCESS conditions can be seen in Table 12.

Table 12

Means, standard deviations and one-sample t-test results of comparisons of mental effort sub-components across the MANAGEABLE and EXCESS conditions

	M	*SD*	One-sample *t*-test (two-tailed)
Mental Effort Component			
Checking approach	4.00	1.77	$t(14) = -2.19, p < .05$
Deciding on next action	3.47	1.46	$t(14) = -4.08, p < .01$
Implementing actions	4.67	1.68	$t(14) = -.77, p > .05$
Scanning the environment	4.13	2.00	$t(14) = -1.68, p > .05$

Note: N = 15, Responses to these items were given on a 9-point Likert-type scale: 1 = more mental effort when I had MANAGEABLE fire trucks, 5 = the same, and 9 = more mental effort when I had EXCESS fire trucks. One-sample *t*-test was performed against a test value of 5, which participants would have circled if they felt no difference between conditions.

As can be seen in Table 12, participants expended more mental effort checking that they were using the right approach and deciding which action to take next in the MANAGEABLE condition. Therefore, participants allocated more strategic thought to appliance usage in the MANAGEABLE condition compared to the EXCESS condition. Also, mental effort expended implementing actions was not significantly

different between the conditions. Finally, the finding of no significant difference in mental effort scanning the environment for changes between conditions suggests that the same mental effort was dedicated to situation assessment and SA maintaining procedures in both conditions.

Pearson correlations were performed between participants' overall mental effort expended and specific components that such mental effort was expended on in NFC. Table 13 contains the results of such correlations.

Table 13

Correlations between the overall mental effort item and specific mental effort sub-components in the MANAGEABLE and EXCESS conditions

	Overall Mental Effort	
	MANAGEABLE	EXCESS
Mental Effort Component		
Scanning the environment	.36	.64**
Deciding on next action	.14	.68**
Implementing actions	.15	.34
Checking approach	.35	.61**

Note: *p<.05 (1-tailed), **p<.01 (1-tailed), N = 15

Table 13 shows that the less mental effort overall in the EXCESS condition was accompanied by less effort scanning the environment for changes, deciding on what action to take next and checking the right approach was being used. In examining the overall pattern of these correlations, it can be noted that stronger associations were obtained in the EXCESS condition than in the MANAGEABLE condition.

Attention to All Parts of the Scenario

Global SAGAT score was positively related to the item assessing participants' attention to all parts of the scenario in both the MANAGEABLE condition (r = .47) and the EXCESS condition (r = .46), although the latter did not quite reach

significance level. No other correlations between this attention item and other variables were found.

Participant Awareness of Compulsion to Use All Appliances

Participants indicated on a 9-point Likert-type scale (1 = not compelled to use all appliances, 9 = very compelled to use all appliances) that they were aware of a strong compulsion to use all available appliances across MANAGEABLE and EXCESS conditions overall (M = 7.53, SD = 1.77). Furthermore, a one-sample *t*-test was performed against a test value of 5, which found that the mean level of experienced compulsion was significantly greater than a moderate awareness level of compulsion $t(14) = 5.55$, $p = .00$ (two-tailed).

Maximum Number of Appliances That Could Be Cognitively Managed

For further insight, the maximum number of appliances manageable variable (as determined by the experimenter on the basis of the mean idle time) was correlated with all demographic variables, performance scores and global SAGAT scores, the results to which can be seen in Table 14.

Table 14

Correlations between the maximum number of appliances manageable variable and performance scores, global SAGAT scores and all demographic variables

	Maximum Number of Appliances Manageable
Demographic Variables	
Participant age	-.21
Days a week using computer	.40
Rating of computer skills	.28
How comfortable moving mouse	.46
How often play computer games	.73**
Rating of coping ability under pressure	.15
Experience with decision making under time pressure	.10
Performance Scores	
MANAGEABLE condition	.77**
EXCESS condition	.69**
Global SAGAT Scores	
MANAGEABLE condition	.17
EXCESS condition	.18

Note: *p<.05 (1-tailed), **p<.01 (1-tailed), N = 15.

As can be seen in Table 14, how often participants played computer games was significantly correlated to the maximum number of appliances they could cognitively manage. Furthermore, an independent samples t-test revealed that males (M = 6.20, SD = 1.30) could cognitively manage more fire fighting appliances than females (M = 5.00, SD = 0.67), $t(13) = 2.40$, $p<.05$ (2-tailed?), d = 1.33. The large range in the maximum amount of appliances that could be managed does, in fact, reflect genuine differences in cognitive capacities. As expected therefore, the higher the number of appliances a participant could cognitively manage, the higher their performance in both the MANAGEABLE and EXCESS conditions.

Participants Who Performed Exceptionally Better In a Particular Condition

Residualised change scores to identify participants as showing an unduly positive or negative change in performance from MANAGEABLE to EXCESS conditions were calculated. Following this, the top and bottom five participants according to residualised change scores were selected and compared. Specifically, several independent sample *t*-tests were conducted to compare participants who performed particularly poorly in the EXCESS condition relative to the MANAGEABLE condition, with participants who performed particularly better in the EXCESS condition relative to the MANAGEABLE condition, on all main study variables and self-report items.

As expected, there was a significant difference in performance in the EXCESS condition between participants relatively better in MANAGEABLE (M = 62.91, SD = 13.55) and participants relatively better in EXCESS (M = 84.23, SD = 9.07), $t(8) = -2.92$, $p<.05$ (1-tailed), d = 2.06. Interestingly, it was also found that participants who were relatively better in MANAGEABLE expended significantly more mental effort deciding what action to take next in the EXCESS condition (M = 7.70, SD = .97) compared to participants relatively better in EXCESS (M = 4.80, SD = 1.79), $t(8) = 3.18$, $p<.05$ (2-tailed), d = 2.25. Additionally, it was found that participants who were relatively better in MANAGEABLE expended significantly more mental effort checking that they were using the right approach in the EXCESS condition (M = 6.00, SD = 0.00) compared to participants relatively better in EXCESS (M = 3.80, SD = 1.79), $t(8) = 2.75$, $p<.05$ (2-tailed), d = 1.94. Therefore, participants relatively better in MANAGEABLE allocated more strategic thought to appliance usage in the EXCESS conditions than participants relatively better in EXCESS.

It would be expected that the participants relatively better in MANAGEABLE would have had a higher mental workload and struggled handling this mental workload in the EXCESS condition. In accordance, participants relatively better in MANAGEABLE expended significantly more mental effort overall in the EXCESS condition (M = 7.20, SD = 1.30) compared to participants relatively better in EXCESS (M = 5.40, SD = 1.14), $t(8) = 2.32$, $p<.05$ (1-tailed), $d = 1.64$. Also, participants relatively better in MANAGEABLE had significantly more difficulty managing their mental workload in the EXCESS condition (M = 5.40, SD = 1.95) compared to participants relatively better in EXCESS (M = 3.00, SD = 2.00), $t(8) = 1.92$, $p<.05$ (1-tailed), $d = 1.35$. No other significant relationships were found for any other variable.

Discussion

Overview

The first part of this section comprises a discussion of the results of the preliminary analyses. This includes a discussion of the effect of demographic variables and of the adequacy of NFC to study DDM. Following consideration of the results of the preliminary and supplementary analyses, the results of the main analyses are discussed in terms of the specific hypotheses. Finally, practical implications of the findings and suggestions for future research are discussed. As has already been mentioned, the correlations must be interpreted cautiously because of the small sample size. Nonetheless, such results give some insights into the interpretation of the main findings.

Preliminary Analyses

Demographic Variables

Interestingly, the more frequently participants played computer games, the higher their performance score was in both appliance availability conditions. Future research using a larger sample is needed to investigate whether participants who play computer games more frequently are more efficient decision makers in computer simulated microworlds such as NFC, or just more practised at the psychomotor skills involved in managing the interface.

Also interesting is the relationship between gender and decision making performance. Specifically, males could cognitively manage significantly more appliances than females. Furthermore, males performed significantly better than females in the EXCESS condition, and slightly but not significantly better in the MANAGEABLE condition. It is important to note however, only five males were tested in the present study compared to ten females. Again, future research using a larger sample is needed to re-investigate these findings. Specifically, such future research should explore whether males in general have greater overall cognitive capacity and processing efficiency than females with respect to complex dynamic tasks, or are just more practiced at the psychomotor skills involved in managing the NFC interface. Furthermore, future research should explore the possibility that males may have more effective task management strategies to deal with an over-abundance of resources.

Adequacy of the NFC Task for Studying DDM

Overall, participants reported experiencing a heavy workload and expending a large amount of mental effort in both appliance availability conditions. Therefore, the NFC trials were sufficiently cognitively demanding to test the research hypotheses in the present study. Interestingly, participants generally did not report having significant difficulty managing their mental workload in either condition. This seems to suggest that the participants generally had effective task management strategies to deal with the task load in both conditions. However, as it will be discussed later, there were in fact individual differences in the ability to appropriately adapt to the extra resources in the EXCESS condition.

Main Research Analyses

As it will become apparent, the level of strategic thought allocated to appliance usage by participants in both conditions merits attention in the discussion of the decision making performance results. Hence, these items are discussed in the following section addressing the results of the first hypothesis instead of in the section addressing the final hypothesis regarding mental workload.

Comparisons of Decision Making Performance and Strategic Thought Between MANAGEABLE and EXCESS Conditions

The hypothesis that decision making performance would be better in the MANAGEABLE condition compared to the EXCESS condition was not supported. In fact, there was no significant difference in performance between appliance availability conditions. Therefore, one might infer that participants were able to deal effectively with the extra appliances in the EXCESS condition without overloading their working memory (Brozovic, 2004). However, if this was the case, their decision making performance should have been better in the EXCESS condition compared to the MANAGEABLE condition because more appliances offer more fire fighting power (Omodei & Wearing, 2004). This was not found, so one might alternatively infer that performance was impaired to at least some extent in the EXCESS condition. Of particular relevance are the results of further analyses suggesting that in fact, the performance of only some participants was impaired in the EXCESS condition (i.e., participants relatively better in MANAGEABLE). Importantly, the results of further analyses also suggest that the more strategic thought allocated to appliance usage in the EXCESS condition, the more decision making performance was impaired in that condition. This finding is discussed in more detail below.

Participants who performed relatively better in the MANAGEABLE condition allocated more strategic thought to appliance usage in the EXCESS condition than participants who performed relatively better in EXCESS. Therefore, participants relatively better in MANAGEABLE appeared to be trying to utilize the over-abundance of appliances in a more strategic manner, which led to their working memory and attention capacities being exceeded. In support of this, participants relatively better in MANAGEABLE had a higher mental workload and had more difficulty managing their mental workload in the EXCESS condition than participants relatively better in EXCESS, a finding that will be discussed in further detail later.

In light of these results, the sacrifice of strategic thought to take advantage of the extra appliances in the EXCESS condition seemed appropriate for achieving control of the simulated spreading fires in NFC. Conversely, the use of appliances in a strategic manner was perhaps advantageous in the MANAGEABLE condition. Providing support for this, participants overall allocated more strategic thought to appliance usage in the MANAGEABLE condition than in the EXCESS condition. It

is important to note that this finding also suggests that even participants relatively better in MANAGEABLE perhaps reduced strategic thought associated with appliance use, at least to some extent, in the EXCESS condition.

Perhaps the attempt to use the over-abundance of appliances meant that some decrement in strategic thought was inevitable. Specifically, participants would have had fewer cognitive resources available for strategic thought. However, perhaps participants relatively better in MANAGEABLE did not sacrifice strategic thought in the EXCESS condition to the same extent that participants relatively better in EXCESS did. Therefore, it may be said there are perhaps individual differences in the *extent* to which strategic thought is sacrificed in the presence of an over-abundance of resources. Future research using a larger sample is needed to investigate this proposition.

The general finding that participants sacrificed strategic thought more in the EXCESS condition provides some evidence that the participants were perhaps compelled to use the over-abundance of appliances. Important to note however, the finding of no-difference in self-perceived performance between the conditions is contrary to the proposal that *all* people believe “more is better” with regard to information and other decision resources. Rather, only some individuals might hold this belief. Also important to note, perceptions of performance generally correlated with actual performance and therefore, the low correlation in such perceptions across conditions suggest participant insensitivity to the effect of the resource availability manipulation on their performance. Such results may have important implications for the current theoretical understanding regarding the overutilisation bias. Specifically, there may be individual differences in the extent to which such a compulsion to use all available appliances is experienced, which was not assessed in the present study. Therefore, future research investigating the overutilisation bias should perhaps incorporate a measure of the extent of compulsion to use all resources in each resource availability condition. Suggestions for ways to measure this compulsion will be discussed in further detail later.

Comparison of Mental Workload Between MANAGEABLE and EXCESS Conditions

The hypothesis that mental workload would be lower in the MANAGEABLE condition compared to the EXCESS condition was not supported. Mental effort

expended overall, difficulty managing mental workload and the extent to which participants felt they had a heavy mental workload were not significantly different between the two conditions. Importantly, participants reported high motivation and reported expending a high amount of mental effort in both appliance availability conditions. Therefore, there may have been a ceiling effect for the mental workload items, whereby the self-reported levels for these items could not get any higher in the EXCESS condition than they already were in the MANAGEABLE condition (Brozovic, 2004). Alternatively, one might interpret the results as again suggesting that participants were able to deal effectively with the extra appliances in the EXCESS condition without overloading their working memory. However, as it has already been argued, there were in fact individual differences in this ability. Likewise therefore, there were perhaps individual differences in the level of mental workload experienced across conditions.

Support for such individual differences in mental workload exist in the aforementioned finding that participants relatively better in MANAGEABLE had a significantly heavier mental workload and had significantly greater difficulty managing their mental workload in the EXCESS condition, compared to participants relatively better in EXCESS. In light of these results, it may also be that the participants relatively better in MANAGEABLE had poorer metacognitive control and thus poorer ability to self-monitor and self-regulate the state of their working memory in the EXCESS condition (Omodei, Wearing, McLennan, Elliot & Clancy, 2001; Omodei et al., 2003). Therefore, it may be concluded that there are individual differences in the ability for metacognitive control, and for self-monitoring and self-regulation of the state of working memory in the presence of an over-abundance of resources.

It must be acknowledged that participants who were relatively better in MANAGEABLE still only reported having moderate difficulty managing their mental workload in the EXCESS condition. However, the fact that these participants had such poor self-regulation and self-monitoring of the state of their working memory meant they were not entirely aware of the extent to which they were actually struggling to manage their mental workload in the EXCESS condition. As previously noted, such participants subsequently tried to use all appliances in the EXCESS condition in a strategic manner. Future research is needed to test such individual

differences in the experience and management of high mental workload in DDM environments.

Comparison of Situation Awareness Between MANAGEABLE and EXCESS Conditions

The hypothesis that participants' SA would be better in the MANAGEABLE condition than the EXCESS condition was not supported. Rather, there was no significant difference in SA between the conditions. Considering that participants generally did not feel cognitively overloaded, one might suggest that such a result is understandable. Specifically, one may infer that participants had the cognitive resources available to maintain a similar level of SA in the EXCESS condition that they had achieved in the MANAGEABLE condition. However, this inference is invalidated by certain results obtained from further analyses, which are discussed below.

Participants relatively better in MANAGEABLE would have presumably had less available cognitive capacity for situation assessment and thus SA maintaining procedures than participants relatively better in EXCESS. This is because participants relatively better in MANAGEABLE had a higher mental workload and greater difficulty managing their workload in the EXCESS condition. Nonetheless, there was no significant difference in SA in the EXCESS condition between participants relatively better in MANAGEABLE and participants relatively better in EXCESS. Even more interesting was the finding that there was no significant difference in SA between these participants in the MANAGEABLE condition. It may be the case that these participants simply had equal ability for acquiring and maintaining adequate SA (Endsley & Bolstad, 1994). Specifically, the participants may have had similar spatial, perceptual, attention sharing and pattern matching skills (Endsley & Bolstad). However, in the present study, the extent of such skills in participants can only be inferred from SA scores. Future research on the specific factors that influence one's ability to acquire and maintain SA is needed.

Nonetheless, participants relatively better in MANAGEABLE and participants relatively better in EXCESS must have dedicated similar amount of cognitive capacity to situation assessment and thus SA maintaining procedures in both conditions. In support of this, self-reports of attention to all parts of the scenario and mental effort

expended scanning the environment for changes was not different in either condition between these participants.

The lack of correlation between SAGAT scores and self-perceived SA merits attention. In effect, this suggests that self-reports of situation awareness are unlikely to provide a reliable or valid indicator of such awareness, but may provide useful information on the persons' own reactions to the task across the various conditions. Hence, future studies may benefit from continuing to use this item.

Also interesting to note, participants who had a heavier mental workload and expended more mental effort overall in the EXCESS condition achieved a lower SAGAT score. This provides small yet noteworthy evidence that the development and maintenance of higher order SA may be hindered by heavy mental workload (Brozovic, 2004). However, despite the differences in mental workload, SA and self-reported attention to all parts of the scenario in both conditions were not significantly different between participants relatively better in MANAGEABLE and participants relatively better in EXCESS. Therefore, future research is needed to investigate the difference in SA between participants who do and do not make appropriate changes in their strategies in the presence of more resources than can be cognitively managed. Specific ways of assessing the nature and effectiveness of strategies people use to deal with an over-abundance of appliances will be proposed later.

Also interesting was the finding that the correlations between decision making performance and SA were positive and approaching significance, especially for the EXCESS condition and averaged across conditions. Again, future research using a larger sample is needed to investigate this finding. Specifically, future research should explore Endsley's (1995a) proposition that SA might increase the probability of good decision making performance, but cannot necessarily guarantee it.

Potential Limitations of the Present Study

One might argue that a limitation of the present study was the measurement of SA, because the three levels of SA were not individually assessed. However, as it has been discussed, items included on the SAGAT to measure the specific levels would not have been reliable because of memory decay. Fortunately, the fire perimeter item was a global measure of SA, which required L1, L2 and L3 SA. Providing small but valuable support for this argument, participants who reported good attention to all parts of the scenario rather than one aspect of the scenario achieved significantly

better global SAGAT scores, especially in the MANAGEABLE condition. Certainly, the idea of using only one item on the SAGAT questionnaire, which essentially measured global SA, was appropriate for avoiding the issue of memory decay typically encountered in previous studies using NFC.

One might also express concern about the reliance on the mean idle time statistic as a measure of the maximum amount of appliances one could cognitively manage. It might be suggested that individual differences in the psychomotor skill, errors made in the initiation of commands and in the strategies used to deal with appliances could affect the mean idle time value. However, participants with low psychomotor skill, who made more errors or who were slower in the implementation of commands due to strategic thought, would have presumably had less remaining cognitive capacity for extra appliances than other participants. Hence, the maximum amount of appliances that could be cognitively managed would consistently give a mean idle time of 70%, regardless of skill level and strategy use.

The fact that the NFC trial replays only show the appliances responding to a specific command means it is unclear whether noticeably long periods of time of no action are the result of poor participant psychomotor skill, action implementation error, or time spent by the participant strategising about the placement of appliances. Therefore, individual differences in the extent of experienced compulsion to use all resources and in the extent of quantity-quality trade-offs could not be reliably assessed in the present study. Needless to say, the results of the present study are still valuable, yet future insight could be gained into the nature of the overutilisation bias if the NFC program was improved to incorporate the mouse cursor activity in trial replays.

Practical Implications of Findings

Most importantly, the present study has contributed a unique perspective to the research already conducted on the nature of the overutilisation bias. Perhaps it is not sufficient to generalise that all people suffer from a deeply embedded cognitive bias of a tendency to overuse, nor is it appropriate to generalise that people are generally poor decision makers when there is an over-abundance of resources. In fact, it has become apparent that despite human processing limitations, some people can take advantage of the performance edge offered by the availability of an abundance of resources.

This finding has important practical implications. Previous suggestions of Omodei and colleagues to restrict the number of resources available to decision makers in DDM situations may not be relevant for all individuals. In fact, more resources may be better for some individuals, but only if they are able to adapt their decision making strategies to take advantage of the over-abundance of resources. Therefore, perhaps the focus should be on developing training programs that assist people to adapt to variations in resource availability.

The finding of individual differences in the maximum number of resources that can be cognitively managed also has important practical implications. Selecting emergency management personnel who can cognitively manage a large number of resources to be leading decision makers in the DDM situations would be appropriate for minimising the potential for fatal error and maximising the potential for control.

Suggestions for Future Research

Much in the same way as in the present study, future research investigating the possibility of an overuse of resources bias in NFC generated scenarios ought to control for individual differences in the maximum number of resources one can cognitively manage. The use of the mean idle time statistic as a measure of the maximum amount of appliances one can cognitively manage was reliable, and warrants use in future research. Also, the shortened version of Endsley’s (1995b) SAGAT was reliable, and warrants use in future studies investigating people’s SA in NFC.

If the NFC trial relays were improved to show mouse cursor activity, perhaps future researchers could use NFC trial replays to assess the extent to which people feel compelled to use an over-abundance of resources. From this, the extent to which participants observably make trade-offs between the quantity of resources used and the quality of strategic thought associated with such resource use could be inferred.

Despite the results of the present study, perhaps it is not appropriate to generalise that decreasing strategic thought is an appropriate strategy for every person. Individual differences in experience, psychomotor skill, cognitive capacity and processing efficiency might mean there are differences in the extent to which sacrificing quality of strategic thought to deal with the over-abundance of appliances is effective. This remains an avenue worthy of exploration in future studies.

It is interesting to note that the need for cognitive closure may be a predictor of whether the sacrifice or maintenance of quality of strategic thought is appropriate for particular individuals when there is an over-abundance of resources in DDM environments. Therefore, future studies should measure people's need for cognitive closure, which is manifested through several different aspects, such as desire for predictability, preference for order and structure, and discomfort with ambiguity, decisiveness, and close-mindedness (Webster & Kruglanski, 1994). Specifically, people with low need for cognitive closure are more rapid decision makers, so the sacrifice of quality of strategic thought to take advantage of an over-abundance of appliances would be appropriate for them (Joslyn & Hunt, 1998; Webster & Kruglanski, 1994). Conversely, people with a high need for cognitive closure would prefer and benefit from using fewer appliances in a strategic, orderly and structured manner. A measure of the need for cognitive closure could be obtained using the Need for Cognitive Closure Scale commonly used in social cognition research, which was found to be a highly reliable and valid instrument (see Webster & Kruglanski, 1994, for extensive discussion and review of the Need for Cognitive Closure Scale).

Future studies should measure people's psychomotor skill, which could also be considered in the process of rating the effectiveness of quantity-quality trade-offs made by participants. Those with quick psychomotor skill can achieve control of spreading fires in NFC through the quick implementation of actions, so sacrificing quality of strategic thought to take advantage of an over-abundance of appliances would be an appropriate strategy for such participants. Conversely, participants with slower psychomotor skill would benefit from using a select few appliances in a strategic manner rather than trying to use all available appliances. A measure of participants' psychomotor skill could be obtained by having them complete a simple NFC trial, where they are instructed to complete a series of specific commands in the quickest possible time.

Conclusion

The present study investigated the purported phenomenon of the human tendency to overuse resources, called the overutilisation bias, after controlling for individual differences in the number of resources cognitively manageable. It was generally found that, in the presence of more appliances than could be cognitively managed, participants' mental workload, SA and decision making performance were not significantly affected. However, these results also suggest that participants generally did not appear to be able to take advantage of the performance edge offered by the availability of an over-abundance number of resources. Of major interest, further analyses revealed there may be individual differences in the extent of compulsion experienced to use an over-abundance of appliances when made available. Furthermore, there were individual differences in the ability to appropriately adapt decision making strategies to take advantage of the overabundance of resources. In the present study, allocating less strategic thought to appliance usage to take advantage an over-abundance of appliances was appropriate for achieving control of the dynamic situation in NFC.

However, it was acknowledged there may in fact be individual differences in the extent to which specific quantity-quality trade-offs are appropriate. It was suggested that one's need for cognitive closure and one's psychomotor skill may predict what quantity-quality trade-off might be appropriate in the presence of an over-abundance of decision making resources. This remains to be determined by future research.

It is concluded that individual flexibility in the quality of strategic thought allocated to resource usage may well be a major predictor of decision making efficiency in dynamic environments such as those encountered by fire fighters. Hence, individual differences in strategic flexibility merit investigation in future research into the nature of decision making under varying levels of decision resource availability.

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Appendices

APPENDIX A

BACKGROUND INFORMATION QUESTIONNAIRE

Question 1

a) Please circle one number to show: Male = 1 Female = 2

b) Age in years ______

Question 2

Computer Experience: (circle one number per question)

a) How many days per week, on average, do you use a computer?

0	1	2	3	4	5	6	7

b) In general, how good are your computer skills?

1	2	3	4	5	6	7	8	9
Very poor				*Average*				*Advanced*

c) How comfortable do you feel manoeuvring a computer mouse?

1	2	3	4	5	6	7	8	9
Very uncomfortable *The mouse is very distracting and difficult to use*								***Very comfortable*** *I don't even think about it*

d) How often do you play computer games?

1	2	3	4	5	6	7	8	9
Never				*Sometimes*				*All the time*

Question 3

a) How well do you cope under pressure, when decisions need to be made quickly and accurately?

1	2	3	4	5	6	7	8	9
Very poorly				*Average*				*Very well*

b) Have you had much experience making decisions under time pressure and uncertainty (ie emergency, stressful, managerial situations)?

1	2	3	4	5	6	7	8	9
No experience				*Some experience*				***A lot of experience*** *I have to make these kinds of decisions every day*

END OF QUESTIONNAIRE

APPENDIX B

SAGAT QUESTIONNAIRE

It is important in completing this task that you provide your first impressions rather than careful consideration as to whether you might be right or wrong. That is, just do as well as you can without focusing on whether your responses are right or wrong.

Question 1

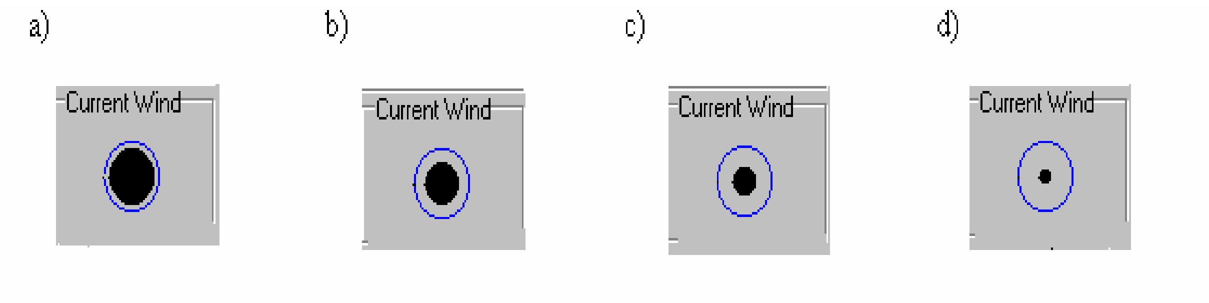
On the clear acetate sheet on the computer screen;

i. Out of the fires that are still burning, use the black pen to draw the fire that is threatening the most valuable landscape.

ii. Using the blue pen, mark the location where the next fire is due to break out.

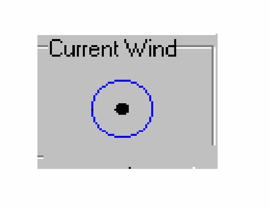
Question 2

Which of the pictures below most closely matches the strength of the current wind?



Question 3

On the picture, please mark the direction of the current wind.



END OF QUESTIONNAIRE

APPENDIX C

INDIVIDUAL TRIAL SUBJECTIVE EXPERIENCE QUESTIONNAIRE

The following questions relate to your experience in the trial you have just completed. Please indicate your answer to each of the following questions by circling one number on the scale provided.

Question 1

a) How well do you think you performed in terms of the value of landscape saved in the <u>last</u> Fire Chief trial?

1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
not well at all								*very well*

Question 2

a) How <u>determined</u> were you to perform as well as you could on the <u>last</u> Fire Chief trial?

1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
not determined at all								*very determined*

b) How much <u>mental effort</u> did you put into the <u>last</u> Fire Chief trial?

1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
no effort								*a great deal of effort*

Question 3

a) To what extent did you feel that you had a heavy workload during the last Fire Chief trial?

1	2	3	4	5	6	7	8	9
very light workload								*very heavy workload*

b) How difficult was it for you to manage the mental workload required of you in the last Fire Chief trial?

1	2	3	4	5	6	7	8	9
not difficult at all								*very difficult*

c) In the last Fire Chief trial how much mental effort did you expend overall?

1	2	3	4	5	6	7	8	9
no mental effort								*a great deal of mental effort*

d) In the last Fire Chief trial how much mental effort did you expend scanning the environment for changes or new developments?

1	2	3	4	5	6	7	8	9
no mental effort								*a great deal of mental effort*

e) In the last Fire Chief trial how much mental effort did you expend deciding what action to take next?

1	2	3	4	5	6	7	8	9
no mental effort								*a great deal of mental effort*

f) In the <u>last</u> Fire Chief trial how much mental effort did you expend on <u>implementing the actions</u> you had decided on?

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
no mental effort								*a great deal of mental effort*

g) In the <u>last</u> Fire Chief trial how much mental effort did you expend on <u>controlling your emotional reactions</u> to the situation?

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
no mental effort								*a great deal of mental effort*

h) In the <u>last</u> Fire Chief trial how much mental effort did you expend on <u>checking</u> that you were using the right approach to the situation?

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
no mental effort								*a great deal of mental effort*

Question 4

a) How would you describe your <u>overall awareness</u> of what was going on during the <u>last</u> Fire Chief trial?

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
very low awareness								*very high awareness*

b) To what extent were you aware of the overall <u>distribution</u> of fire trucks during the <u>last</u> Fire Chief trial?

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
not aware at all								*very much aware*

c) To what extent were you aware of the current wind conditions during the <u>last</u> Fire Chief trial?

1	2	3	4	5	6	7	8	9
not aware at all								*very much aware*

d) To what extent were you aware of the forecast wind conditions during the <u>last</u> Fire Chief trial?

1	2	3	4	5	6	7	8	9
not aware at all								*very much aware*

e) To what extent were you aware of fire warnings during the <u>last</u> Fire Chief trial?

1	2	3	4	5	6	7	8	9
not aware at all								*very much aware*

f) How well do you feel you <u>prioritised</u> the different fire fronts in the <u>last</u> Fire Chief trial?

1	2	3	4	5	6	7	8	9
not well at all								*very well*

g) In the <u>last</u> Fire Chief trial, to what extent did you find yourself becoming so involved with fighting a particular fire, that you <u>didn't</u> pay attention to what else was happening in other parts of the screen?

1	2	3	4	5	6	7	8	9
very involved with just one fire, did <u>not</u> pay attention to other parts								*never involved in just one fire, <u>always</u> paid attention to other parts*

END OF QUESTIONNAIRE

APPENDIX D

AFTER ALL TRIALS QUESTIONNAIRE

The following questions relate to your experiences in the last four trials you have just completed. Please indicate your answer to each of the following questions by circling one number on the scale provided.

Question 1

Overall, in which Fire Chief trials do you think you performed best on?

1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
performed best when I had _ fire trucks				*the same*				*performed best when I had _ fire trucks*

Question 2

a) In general, to what extent did you feel compelled to use all the fire trucks at your disposal?

1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
not compelled at all								*very compelled*

b) To what extent did you deliberately keep some fire trucks idle when you had _ fire trucks available?

1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
never								*always*

c) To what extent did you deliberately keep some fire trucks idle when you had _ fire trucks available?

1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
never								*always*

Question 3

a) In which Fire Chief trials did you feel you had a heavier mental workload?

1	2	3	4	5	6	7	8	9
heavier mental workload when I had _ *fire trucks*				*same*				*heavier mental workload when I had _ fire trucks*

b) In which Fire Chief trials did you feel more confident?

1	2	3	4	5	6	7	8	9
more confident when I had _ fire trucks				*the same*				*more confident when I had _ fire trucks*

c) In which Fire Chief trials did you expend more mental effort <u>overall</u>?

1	2	3	4	5	6	7	8	9
more mental effort when I had _ fire trucks				*the same*				*more mental effort when I had _ fire trucks*

d) In which Fire Chief trials did you expend more mental effort on <u>scanning the environment</u> for changes and new developments?

1	2	3	4	5	6	7	8	9
more mental effort on scanning when I had _ fire trucks				*the same*				*more mental effort on scanning when I had _ fire trucks*

e) In which Fire Chief trials did you expend more mental effort on deciding what action to take next?

_1 2 3 4 5 6 7 8 9_

more mental effort on deciding when I had _ fire trucks	the same	more mental effort on deciding when I had _ fire trucks

f) In which Fire Chief trials did you expend more mental effort on implementing the actions you had decided on?

_1 2 3 4 5 6 7 8 9_

more mental effort on implementing I had _ fire trucks	the same	more mental effort on implementing I had _ fire trucks

g) In which Fire Chief trials did you expend more mental effort on controlling your emotional reactions to the situation?

_1 2 3 4 5 6 7 8 9_

more mental effort controlling emotions when I had _ fire trucks	the same	more mental effort controlling emotions when I had _ fire trucks

h) In which Fire Chief trials did you expend more mental effort on checking that you were using the best approach to the situation?

_1 2 3 4 5 6 7 8 9_

more mental effort on checking when I had _ fire trucks	the same	more mental effort on checking when I had _ fire trucks

Question 4

In the Fire Chief task, the situation is constantly changing (e.g. new fires breaking out, wind direction changing). In which Fire Chief trial did you feel you kept better track of things?

1 2 3 4 5 6 7 8 9

kept better track of things when I had _ fire trucks	*the same*	*kept better track of things when I I had _ fire trucks*

Question 5

In the Fire Chief task, it is usually necessary to place higher priority on some fires over others. In which Fire Chief trials did you feel you set better priorities?

1 2 3 4 5 6 7 8 9

better priorities when I had _ fire trucks	*the same*	*better priorities when I had _ fire trucks*

Question 6

Fire Chief scenarios are so complex and fast-paced that mistakes are inevitable. In which Fire Chief trials did you feel you made more mistakes?

1 2 3 4 5 6 7 8 9

made more mistakes when I had _ fire trucks	*the same*	*made more mistakes I had _ fire trucks*

END OF QUESTIONNAIRE

APPENDIX E

FIRE CHIEF PROTOCOL

Mark the time when you start the experiment (important if participants get paid.)
Give out and collect information statement, consent forms and Demographic Questionnaire.
Have participant sit at the computer.
Experimenter sits on right side of subject.
Have water available for subject.
Have 3 acetate sheets prepared.
Load the demonstration trial. Do NOT begin running it yet.
Explain that you will be reading the protocol so that everyone gets the same instructions.

Ensure you are following and entering file numbers (those in the brackets) not trial numbers when prompted by the computer.

Introduction to the Task

You are participating in a study of complex decision-making that makes use of a computer-simulated fire-fighting task. The simulation task we are using is called Fire Chief. The Fire Chief program is a computer recreation of a real-world fire-fighting situation. It is basically a map of an area where fires break out and your job as the Fire Chief is to extinguish the fires.

Over the next couple of hours you will be trained in the use of the Fire Chief program. First, I will introduce you to the computer simulation with a demonstration and then I'll get you to complete a basic scenario. Then, I'll give you a chance to become more familiar with the program, through five 10 minute practice trials. You will have a short break between each practice trial whereby I will ask you to leave the room so I can make necessary reviews and recordings. At the end of the last practice trial, you will be given a 45 minute break. When you return, you will be run through a 10 minute refresher trial. Then you will be run through two more trials. During the course of these trials, I will ask you to reproduce parts of the fire scenario screen by drawing them onto a transparent film. Finally, you will be run through a further two 10 minute trials and the computer will record your performance on all these trials. During the course of these trials, I'll ask you to fill out brief questionnaires about your experiences as the Fire Chief.

Now, I will concentrate on showing you how to operate the computer simulation and give you a chance to have a go yourself. At first, it may seem as though there is a lot of new information for you to take in but try and remember. The long explanations will usually be followed by an opportunity for you to have a go on the computer yourself. Having said that; please feel free to ask questions at any stage throughout the practice sessions.

Bring the demonstration trial up. **<u>Go through this slowly.</u>**

Explanation of Task Features

i) Landscape

What you can see on your screen is a demonstration map, which shows the different types of landscapes and fire fighting appliances.
The brown houses represent residential areas.

[POINT OUT using pen/curser]

All the green areas represent bushland.

[POINT OUT using pen/curser]

All the blue areas represent water sources.

[POINT OUT using pen/curser]

ii) Fire Trucks

Fire fighting trucks are also referred to as appliances. The trucks are based at various fire stations in the trials.

Fire stations: solid red squares

Trucks: light blue outlined squares

[POINT OUT using pen/curser]

Trucks and fire stations cannot be burnt.

iii) Fire Fighting Priorities

The task is designed so that, just as in real life, some landscape features are more important than others. Residential areas are the most important areas to save from fire destruction. Therefore, bushland is less important than residential areas. Remember this when fighting the fires. While there may be a lot of fires spreading in a trial to the point that it may feel overwhelming, you can still achieve a high performance score if you are concentrating on saving the houses.

The comparative value for each landscape feature is:

Housing: 100 points

Bushland: 1 point

Let's start the demonstration.

START demonstration trial.

iv) Fires

You will see on the screen that a fire has broken out. The fires are represented by the orange flames. Once landscape is burnt it turns black and cannot be burnt again.

[POINT OUT using pen/curser]

There is therefore no use trying to save landscape that has already burnt out. Fires with orange flames are the ones that are currently burning and need to be extinguished.

v) Simulation Running Time

The number on the top left-hand side of the screen indicates the number of minutes and seconds that have passed since the start of the simulation.

[POINT OUT using pen/curser]

vi) Wind Direction, Wind Strength and Wind Forecast

With regard to the demonstration we are looking at, you have probably noticed that the fires are spreading more quickly in the _SE_ (*say wind direction that is appropriate for the current trial*) direction than in other directions. This is because the fires spread in the direction of the wind, and the stronger the wind the faster the fire spreads. The current wind details are represented by the wind gauge near the top left-hand side of your screen.

[POINT OUT using pen/curser]

The size of the blue solid circle represents the strength of the wind. A large circle indicates strong wind while a small circle indicates a light breeze. The outer circle is the maximum wind strength. So, at the moment the wind strength is __6_____(*give answer that is appropriate for the current trial*)

[POINT OUT using pen/curser]

The red line that is pointing out from the circle indicates the direction that the wind is blowing. At the moment the wind is blowing to the _SE____ *(say wind direction that is appropriate for the current trial)*

[POINT OUT using pen/curser]

There is also a second wind gauge below the first. This second wind gauge indicates the direction and strength that the wind is <u>forecast</u> to change to.

[POINT OUT using pen/curser]

The time that the wind is due to change is indicated immediately above.

[POINT OUT using pen/curser]

It is important to monitor the wind forecast, as the spread of the fire will change as the wind changes. This will also mean that housing which has not previously been threatened by the fire may be threatened if the wind changes. In the past, we have noticed that good Fire Chiefs monitor the wind forecast regularly and fight the fire accordingly.

Do you have any questions?

vii) Flammability

Now I'd like to introduce you to another aspect of the Fire Chief program. In this program, fires spread faster through some areas than others. That is, there are different fire spread rates.

Fires spread faster through the bushland than through the residential areas.

These 2 fires were approximately the same size when they began. What we will see is that the fire in the bushland burns quite quickly, while the one in the housing does not.

[POINT OUT using pen/curser]

This will be important to remember when you are deciding how to attack the fire. Obviously although it is important to attend to fires that are burning houses, it is also important to put out fires that are burning through forest because it spreads so quickly. Likewise, you may be able to leave for a while fires that are only burning through clearing.

viii) Fire Warnings

The last feature of the program that you need to know about, are fire warnings. Fire warnings are received from the weather bureau based on weather conditions and the degree of flammability of particular sections of landscape at a given time. It is safe to assume that the warnings given by the weather bureau are very reliable, and will pinpoint the time and location of a fire with great accuracy.

In the trials, fire warnings are represented by a red cross. The location of the warning represents the location of the future fire.

[POINT OUT using pen/curser]

If you move the curser over a fire warning, the time that the fire will break out is shown at the bottom of the screen.

[POINT OUT using pen/curser]

I’ll now show you how to use the trucks.

Restart demo trial

Controlling Appliances

i) Moving Trucks

At the beginning of each trial, you will have bases containing a certain number of fire trucks. Fire trucks are used to drop water to extinguish the fires. It is your task to move the appliances to fight the fires that break out.

To move an appliance you need to use the mouse. Place the cursor on the appliance you wish to move and you will notice that a "hand" appears.

Click down on the left mouse button, and while holding it down, drag the appliance to the desired position and then let go of the left mouse button.

[Demonstrate how to pick up a truck and move it.]

The appliance will then make its way to this position – its destination is represented by a small light blue square.

[Move 2 of each appliance]

[POINT OUT using pen/curser]

Once the appliance reaches its destination, which happens immediately, you need to click on it once to make it start dropping water on the fire. When water is being dropped, the appliance will be flashing.

[POINT OUT using pen/curser]

The appliances in the fire station will remain there until you move them.

If you miss an appliance and click on an empty square, the computer will beep to let you know.

[Demonstrate]

I will now let you have a practice of how to move trucks.

Give mouse to participant

Have them move a few trucks

ii) Refilling Appliances with Water

In order to check what the appliance is doing and the percentage of water it has left, place the cursor over the appliance without clicking and look at the information that appears at the bottom of the screen.

[POINT OUT using pen/curser]

All appliances start out 100% full of water at the base. They can drop water 6 times before they run out. When a truck runs out of water, it first tries to drop water on the fire but it cannot do so. It will then stop flashing and remain idle. When this happens you will need to drag the appliance to a water source, where it will refill. You do not need to wait until the appliance is <u>completely</u> empty to refill, appliances can be refilled at any time no matter what the current water level is. Once it has refilled, the appliance will wait at the dam until given instructions on where to go next, ie. it will remain idle at the dam until you move it.

[demonstrate]

It is worth noting that the dams do not have an endless supply of water. As they empty they will change color. When they are dark blue, they are full and when they become empty they turn brown. Generally speaking though, the dams do not run out of water.

iv) Positioning Appliances

Obviously, the strategic and accurate placement of appliances can make a big difference to success in fighting the fires.

It's worth noting that these trials are not designed such that every fire can be extinguished. Furthermore, these trials have not been designed so that every house can be saved. Your job is to save as many houses as you can and to attempt control of the fires.

Certainly, the trials may seem quite difficult at times in terms of the number of fires that break out and are spreading. Just as in real-life, some parts of fires must be ignored in order to save important aspects of the landscape such as the houses, so you have to prioritise.

Therefore, when a trial seems quite hard or even overwhelming, remember you may still be performing extremely well if you are saving houses. You receive 100 points for saving a house, so you can be performing quite well so long as there are unburnt houses still remaining on the screen.

v) Number of appliances

As you have probably noticed, you will need more than one truck to successfully put out a fire front. Try and experiment during the practice trials by using different numbers of appliances to fight the fires.

If two appliances end up on the same square, it will appear as if there is only ONE appliance there, that is, only one light blue square will be shown on the screen. This light blue square represents the LAST appliance to arrive at that location. If you move this appliance away to a new location the appliance that was hidden underneath it is re-displayed.

Performance Scores

i) Performance Scores

The computer calculates performance scores for each trial you complete. Your performance score will reflect the value of the landscape that you saved (emphasise again the importance of saving houses!)

Do you have any questions?

Close demo trial

Demonstration = approx 20 mins

Practice Trials

At this stage now, let's clarify your role in this experiment. In the following trials, you will be asked to assume the role of the fire chief. As the fire chief**,** you are responsible for a large area in Australia. As an example, imagine it is summer and we are in the midst of our longest heatwave for years. We have had several days already where the temperature has reached 40 degrees, so the landscape is extremely dry. Today is a very hot and windy day. On these days, it is critical to put fires out as quickly as possible, as the longer they burn, the more difficult they are to contain. It is also critical, because the weather bureau has forecast the wind to change several times today.

The area is a mixture of bushland, residential areas and dams. In these trials, your goal as the Fire chief is to try and get the highest score you possibly can by saving as much of the landscape from fire destruction as possible. But remember, your score will be calculated based on the value of landscape that you saved. So as mentioned before, the houses are more valuable and are therefore worth 100 points if saved while the bushland is worth 1 point if saved. So, your first priority should be to save the houses.

Just as in real-life, there are different numbers of fire brigades that can respond to a fire. The brigades that do respond will also differ in how many fire trucks they possess. Therefore, during the trials, the number of fire trucks you will have control over will alternate. You are free to use the trucks in any way you think will get you the highest score. That is, you can use as many or as few as you like and put them in any locations that you want. Once again, you will realise that the fires will not be able to be put out completely, but your job is to contain them as best you can until massive reinforcements arrive. Because you have to deal with these fires on your own for a while it is imperative that you strategise about the best way to control them.
Also, you will realise that you will not be able to save all the houses in a scenario. Your job is to try to save as many houses as you possibly can. Remember, you earn 100 points for saving a house, so while a scenario may seem overwhelming in terms of the number of fires that are spreading, you can still perform extremely well if you are saving houses.

Load up Practice Trial 1

Same scenario for each participant.

i) Practice Trial 1:

Here is a practice trial for you to do by yourself. In this trial you will have access to command <u>4</u> fire trucks.

Have the participant click run and start

<u>Things to do while the training trials are running:</u>

Correct them as much as you can in the early trials so that they get into good habits without influencing overall strategies. (e.g. alert them to appliances that have run out of water)

Once completed, break for 5-10 minutes

OK let's try a different scenario.

a) Demonstration of SAGAT

Load up demonstration SAGAT scene X2 (have one minimised) *with a transparency aligned on screen. ENSURE that* ***you*** *mark the corners of the landscape on the transparency. This is important for scoring later on.*

OK, before we start the next practice trial I will demonstrate how to complete the pictorial questionnaire. For this questionnaire, the computer will pause the trial at any given time.

Ordinarily, once the trial is paused, only the basic landscape features will be left on the screen. The location of fires, fire trucks and wind information will not be shown. But for the purposes of showing you how to complete this questionnaire, we will leave these features on the screen.

Following the order of the questions on the questionnaire…..

On the clear acetate sheet on the computer screen, use the black pen to draw the fire that is threatening the most valuable landscape (out of the fires that are still burning).

[Demonstrate]

Again on the clear acetate sheet, use the blue pen to mark the location where the next fire is due to break out.

[Demonstrate]

Now decide and mark on the actual questionnaire which of the pictures most closely matches the strength of the current wind.

[Demonstrate]

Again on the actual questionnaire, mark the direction of the current wind.

[Demonstrate]

b) Practice Trial 2 with SAGAT

OK, I will now let you try a practice trial that will include the pictorial questionnaire.

Load up practice trial X2 (have one minimised)
Have a transparency ready on the screen. Ensure the corners are marked

In this trial you will have access to command 4 fire trucks. When the trial stops, complete the pictorial questionnaire.

Have the participant click run and start
Have the bare landscape minimised ready to bring up after pause
When done (close the bare landscape, press F4 to enable display, then Ctrl R to run)
Allow participant to finish the trial after they have completed the SAGAT

Once completed, break for 5-10 minutes
Add/subtract fire trucks to assess #1 depending on their skill so far.

iii) Assessment trial #1

In this trial you will have access to command ___ fire trucks.

Load up assessment trial #1
Have the participant click run and start

Once completed, break for 5-10 minutes
Assess optimal and adjust accordingly

iii) Assessment trial #2

In this trial you will have access to command ___ fire trucks.

Load up assessment trial #2
Have the participant click run and start

Once completed, break for 5-10 minutes
Assess optimal and adjust accordingly

iii) Assessment trial #3

In this trial you will have access to command ___ fire trucks.

Load up assessment trial #3
Have the participant click run and start

Once completed, break for approximately 45 minutes
Final assessment of optimal and adjust accordingly.
Fill out blank sections (ie: no. of appliances in After All Trials Questionnaire)

Refresher Trial

In this trial you will have access to command (opt___ fire trucks).

Load up refresher trial
Have the participant click run and start

Experimental Trials

Ok, I will now get you to complete two different trials, each with a different scenario and each with a variable number of fire trucks available for command. In these trials, you will be asked to complete the pictorial questionnaire at several times.

Load the experimental trials.
Have the participant click run and start
Administer SAGAT at appropriate intervals
Run to completion

<u>Remember (for refresher and experimental)</u>

For 1 participants, use ORDER 1 (MANAGEABLE, EXCESS), (MANAGEABLE, EXCESS)
For 2 participants, use ORDER 2 (MANAGEABLE, EXCESS), (EXCESS, MANAGEABLE)
For 3 participants, use ORDER 3 (EXCESS, MANAGEABLE), (EXCESS, MANAGEABLE)
For 4 participants, use ORDER 4 (EXCESS, MANAGEABLE), (MANAGEABLE, EXCESS)

ORDER 1:
(MANAGEABLE, EXCESS), (MANAGEABLE, EXCESS)

i) Experimental Trial 1: MANAGEABLE Condition

Set up a transparency on the screen ready for the SAGAT. "This has to be on the screen. You're not to know which trial you will need to do SAGAT". Ensure the corners are marked and note the participant ID number, counterbalancing order and trial number all on the transparency. Do all this without the participant noticing. We don't want them to alter their behaviour in anticipation of having to do the SAGAT.

Load the second experimental trial (MANAGEABLE) X2 (have one minimised)

Have the participant click run and start
Administer the ***SAGAT***
(remember bare landscape, F4 and Cntrl R)

Run Trial to completion

ii) Experimental Trial 2: EXCESS Condition

Set up a transparency on the screen ready for the SAGAT. Ensure the corners are marked and note the participant ID number, counterbalancing order and trial number all on the transparency. Do all this without the participant noticing. We don't want them to alter their behaviour in anticipation of having to do the SAGAT.

Load the second experimental trial (EXCESS) X2 (have one minimised)

Have the participant click run and start
Administer the ***SAGAT*** (remember bare landscape, F4 and Cntrl R)

Run Trial to completion

Once completed, break for approximately 10 minutes

Experimental Trials (3 & 4)

Now we will complete the experimental trials. As was the case in the practice trials, these next scenarios will also have different numbers of appliances available.

Load the third experimental trial

i) Experimental Trial 3: MANAGEABLE Condition

Have the participant click run and start

Run Trial to completion

Administer the ***Individual Trial Subjective Experience Questionnaire***
Load the forth experimental trial (Many condition) while participant is completing the questionnaire

i) Experimental Trial 4: EXCESS Condition

Have the participant click run and start

Run Trial to completion

Administer the ***Individual Trial Subjective Experience Questionnaire***
Load the second experimental trial (Many condition) while participant is completing the questionnaire

(While participant is completing the ***Individual Trial Subjective Experience Questionnaire,*** fill in the blank spaces on the ***After All Trials Questionnaire*** specifying the number of appliances used in the MANAGEABLE and EXCESS conditions by each participant).

"There is one final questionnaire to complete which looks at your experiences over all the experimental trials. Some, but not all, of these questions allow you to report on any differences you may have experienced as a result of change in the number of fire trucks."
Administer ***After All Trials Questionnaire***

<u>*Thank subject for their participation*</u>

OR

<u>ORDER 2:</u>
<u>(MANAGEABLE, EXCESS), (EXCESS, MANAGEABLE)</u>

i) Experimental Trial 1: MANAGEABLE Condition

Set up a transparency on the screen ready for the SAGAT. Ensure the corners are marked and note the participant ID number, counterbalancing order and trial number all on the transparency. Do all this without the participant noticing. <u>We don't want them to alter their behaviour in anticipation of having to do the SAGAT.</u>

Load the first experimental trial (MANAGEABLE) <u>X2 (have one minimised)</u>

Have the participant click run and start

Administer the ***SAGAT*** (remember bare landscape, F4 and Cntrl R)

Run Trial to completion

ii) Experimental Trial 2: EXCESS Condition

Set up a transparency on the screen ready for the SAGAT. Ensure the corners are marked and note the participant ID number, counterbalancing order and trial number all on the transparency. Do all this without the participant noticing. <u>We don't want them to alter their behaviour in anticipation of having to do the SAGAT.</u>

Load the second experimental trial (EXCESS) <u>X2 (have one minimised)</u>

Have the participant click run and start

Administer the ***SAGAT*** (remember bare landscape, F4 and Cntrl R)

Run Trial to completion

Once completed, break for approximately 10 minutes

Experimental Trials (3 & 4)

Now we will complete the experimental trials. As was the case in the practice trials, these next scenarios will also have different numbers of appliances available.

Load the third experimental trial

i) Experimental Trial 3: EXCESS Condition

Have the participant click run and start

Run Trial to completion

Administer the ***Individual Trial Subjective Experience Questionnaire***

Load the second experimental trial (MANAGEABLE condition) while participant is completing the questionnaire

i) Experimental Trial 4: MANAGEABLE Condition

Have the participant click run and start

Run Trial to completion

Administer the ***Individual Trial Subjective Experience Questionnaire***

(While participant is completing the ***Individual Trial Subjective Experience Questionnaire,*** fill in the blank spaces on the ***After All Trials Questionnaire*** specifying the number of appliances used in the MANAGEABLE and EXCESS conditions by each participant).

"There is one final questionnaire to complete which looks at your experiences over all the experimental trials. Some, but not all, of these questions allow you to report on any differences you may have experienced as a result of change in the number of fire trucks."

Administer ***After All Trials Questionnaire***

<u>*Thank subject for their participation*</u>

OR

<u>ORDER 3:</u>
<u>(EXCESS, MANAGEABLE), (EXCESS, MANAGEABLE)</u>

i) Experimental Trial 1: EXCESS Condition

Set up a transparency on the screen ready for the SAGAT. Ensure the corners are marked and note the participant ID number, counterbalancing order and trial number all on the transparency. Do all this without the participant noticing. <u>We don't want them to alter their behaviour in anticipation of having to do the SAGAT.</u>

Load the FIRST experimental trial (EXCESS) <u>X2 (have one minimised)</u>

Have the participant click run and start
Administer the ***SAGAT*** (remember bare landscape, F4 and Cntrl R)

Run Trial to completion

ii) Experimental Trial 2: MANAGEABLE Condition

Set up a transparency on the screen ready for the SAGAT. Ensure the corners are marked and note the participant ID number, counterbalancing order and trial number all on the transparency. Do all this without the participant noticing. <u>We don't want them to alter their behaviour in anticipation of having to do the SAGAT.</u>

Load the second experimental trial (MANAGEABLE) <u>X2 (have one minimised)</u>

Have the participant click run and start
Administer the ***SAGAT X2*** (remember bare landscape, F4 and Cntrl R)

Run Trial to completion

Once completed, break for approximately 10 minutes

Experimental Trials (3 & 4)

Now we will complete the experimental trials. As was the case in the practice trials, these next scenarios will also have different numbers of appliances available.

Load the third experimental trial

i) Experimental Trial 3: EXCESS Condition

Have the participant click run and start

Run Trial to completion

Administer the ***Individual Trial Subjective Experience Questionnaire***
Load the forth experimental trial (MANAGEABLE condition) while participant is completing the questionnaire

i) Experimental Trial 4: MANAGEABLE Condition

Have the participant click run and start

Run Trial to completion

Administer the ***Individual Trial Subjective Experience Questionnaire***

(While participant is completing the ***Individual Trial Subjective Experience Questionnaire,*** fill in the blank spaces on the ***After All Trials Questionnaire*** specifying the number of appliances used in the MANAGEABLE and EXCESS conditions by each participant).

"There is one final questionnaire to complete which looks at your experiences over all the experimental trials. Some, but not all, of these questions allow you to report on any differences you may have experienced as a result of change in the number of fire trucks."
Administer ***After All Trials Questionnaire***

****Thank subject for their participation****

OR

ORDER 4:
(EXCESS, MANAGEABLE), (MANAGEABLE, EXCESS)

i) Experimental Trial 1: EXCESS Condition

Set up a transparency on the screen ready for the SAGAT. Ensure the corners are marked and note the participant ID number, counterbalancing order and trial number all on the transparency. Do all this without the participant noticing. We don't want them to alter their behaviour in anticipation of having to do the SAGAT.

Load the FIRST experimental trial (EXCESS) X2 (have one minimised)

Have the participant click run and start

Administer the ***SAGAT X2*** (remember bare landscape, F4 and Cntrl R)

Run Trial to completion

ii) Experimental Trial 2: MANAGEABLE Condition

Set up a transparency on the screen ready for the SAGAT. Ensure the corners are marked and note the participant ID number, counterbalancing order and trial number all on the transparency. Do all this without the participant noticing. We

don’t want them to alter their behaviour in anticipation of having to do the SAGAT.

Load the second experimental trial (EXCESS) X2 (have one minimised)

Have the participant click run and start

Administer the ***SAGAT*** (remember bare landscape, F4 and Cntrl R)

Run Trial to completion

Once completed, break for approximately 10 minutes

Experimental Trials (2)

Now we will complete the experimental trials. As was the case in the practice trials, these next scenarios will also have different numbers of appliances available.

Load the third experimental trial

i) Experimental Trial 3: MANAGEABLE Condition

Have the participant click run and start

Run Trial to completion

Administer the ***Individual Trial Subjective Experience Questionnaire***

Load the forth experimental trial (EXCESS condition) while participant is completing the questionnaire

i) Experimental Trial 4: EXCESS Condition

Have the participant click run and start

Run Trial to completion

Administer the ***Individual Trial Subjective Experience Questionnaire***

(While participant is completing the ***Individual Trial Subjective Experience Questionnaire,*** fill in the blank spaces on the ***After All Trials Questionnaire*** specifying the number of appliances used in the MANAGEABLE and EXCESS conditions by each participant).

“There is one final questionnaire to complete which looks at your experiences over all the experimental trials. Some, but not all, of these questions allow you to report on any differences you may have experienced as a result of change in the number of fire trucks.”

Administer ***After All Trials Questionnaire***

****Thank subject for their participation****

APPENDIX F

PARTICIPANT DECISION MAKING PERFORMANCE SCORES AND MAXIMUM NUMBER OF APPLIANCES COGNITIVELY MANAGEABLE

Participant ID	Performance MANAGEABLE	Performance EXCESS	Maximum number of appliances that could be cognitively managed
1	64.31	86.24	5
2	56.33	55.68	5
3	53.60	46.71	5
4	60.35	80.17	5
5	62.60	75.45	5
6	89.64	88.34	6
7	62.12	63.80	4
8*	45.79	46.61	4
9	96.41	83.25	7
10	91.01	85.50	6
11	64.51	65.88	5
12	81.44	79.70	5
13	77.82	65.10	5
14	51.13	64.07	4
15	87.96	98.95	8
16	74.81	80.34	6

*Note: Participant 8 was excluded.